RUDIMENTARY TREATISE

ON

CLAY LANDS

AND

LOAMY SOILS;

CONTAINING

THE ORIGIN AND CHEMICAL QUALITIES OF EACH VARIETY OF LAND.—NATURAL PROPERTIES OF THE SOILS AND MODE OF CULTIVATION.—CROPPING AND VALUE OF THE LANDS, AND CHANGES EFFECTED BY MIXING WITH HOT LIME.

BY

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"The sun, which softens wax, will harden clay."—WATTS.

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CLAY LANDS AND LOAMY SOILS.

CHAPTER I.

Designation of Clay.—Chemical and natural Composition of the Earth.

LAY, in the proper derivation of the word, means an unctuous enacious earth, that will mould into various forms. It is the "kley" f the Dutch, the "clai" of the Welsh, and the "claeia" of the axon, which terms have all originated from the Teutonic "kleven," o stick or adhere, because of the clammy adhesive quality of the ubstance. Clay forms a genus of earths, the characters of which re these—they are firmly coherent, weighty, and compact; stiff, iscid, and ductile to a great degree; while moist, smooth to the touch, not easily breaking between the fingers, nor readily diffusible in water, and when mixed, not readily subsiding into it. To constitute clay, the earth must possess sufficient ductility, when kneaded up with water, to be fashioned like paste by the hand on the potter's lathe. This property, rather than colour or composition, determines if an earthy body belongs to the class of 'lays.

It was long considered that clay was the result of the decomposition of felspar and mica, which are two chief ingredients in the constitution of the primitive rocks of granite and gneiss, and that the varieties and modifications have arisen from the different agencies to which the disintegrated matters have been exposed previous to the permanent location. More recent discoveries have found it to be the earth of alum, which is a salt long known and extensively used in dyeing; it is a triple salt—the sulphate, or rather the super-sulphate, of alumina, ammonia, and potash. The analysis of Vauquelin showed the composition to be as under:—

Sulphuric acid	30·52
Alumina	10·50
Potash	10·40
Water	48·58
	100·00

Or,

Sulphuric acid	26·04	or	34·23
Alumina	12·53	"	10·96
Potash	10·02	"	9·81
Water	51·41	"	45·00
	100·00		100·00

Or, more concisely,

Sulphate of alumina	36·70
Potash	18·88
Water	44·42
	100·00

By another statement it contains—

Alumina	15·25	or	10·8
Potash	0·25	„	10·1
Oxide of iron	7·50	„	
Sulphuric acid and water	77·00	„	33·7 acid 5·44 water
	100·00		100·0

Alum is composed of alumina, potash, and sulphuric acid and in its usual form contains a large quantity of water of crystallization. Its octohedral crystals consist of—

Alumina	3 atoms	54	or	10·76
Potassa	1 „	48	„	9·95
Sulphuric acid	4 „	160	„	33·74
Water	24 „	216	„	45·55
Crystallized alum	1	478		100·00

Rock alum occurs in a native solid state at Talfa, in Italy, in great abundance, and contains—

Sulphuric acid	27·05	Or, Silica	24·00
Alumina	31·80	Alumina	43·92
Potash	5·79	Potash	3·08
Silica	28·64	Sulphuric acid	25·00
Water and loss	6·72	Water	4·00
	100·00		100·00

It is found in masses, and in veins running through argillaceous rocks, and in secondary strata, and is got by roasting and lixiviation. Alum slate of Whitby occurs near coals, and differs little from bituminous slate impregnated with pyrites. Alum is used in giving a white colour to bread, in preserving animal substances from putrefaction, in making leather and paper, and also as a mordant in dyeing. A solution of alum turns vegetable blues to red, and, when heated in its water of crystallization, it swells and enlarges much, and produces burnt alum, a light porous dry mass, specific gravity 1·7.

Alumina, or the earth of alum, and the essential ingredient of clay, is a fine white bland powder, adhering strongly to the tongue, but exciting neither taste nor smell. It is insoluble in water and alcohol, but has a considerable affinity for water, increasing in weight about 15 per cent. by absorbing moisture, and retains it with great obstinacy; cold contracts it and squeezes out much water, and it loses weight by the heat evaporating the moisture; dissolves readily in caustic potash, and soda, which distinguishes it from the alkaline earths; after ignition, dissolves slowly in sulphuric and muriatic acids assisted by heat, and may be fused by a violent heat into a white semi-transparent enamel. It unites readily by fusion with other earths, particularly with silica, and much of its utility in the arts arises from this power of union. It unites by fusion with some of the metallic oxides, but not with metals, and forms, by an easy dissolution in acids, many salts more or less soluble and susceptible of crystallization, and others which are insoluble and require an excess of acid. Alumina has a strong affinity for lime if it exceeds the lime in quantity; if the lime be in excess, fusion does not take place. It does not combine with oxygen, or with any of the simple combustibles, and azote has no action in it. It has a strong attraction for colouring matters, and hence the use in dyeing and in calico printing, and in the union with silica and lime forms the basis of all pottery and porcelain, from the coarsest brick to the finest china. Alumina forms a paste with water, and hardens by the action of fire, and loses the first property by acquiring the second; to regain it, the hardened substance must be dissolved in an acid and precipitated. It is made hard enough to give fire with steel, and cut glass with a diamond; when it contains oxide of iron, it emits the well-known earthy smell of clays.

It was early discovered that alum was composed of sulphuric acid, with an earth; but the nature of this earth was long unknown. Stahl and Newman supposed it to be lime, but in 1728 Geoffroy, jun., proved this to be a mistake, and demonstrated that the earth of alum constitutes a part of clay. In 1754 Margraaf showed that the basis of alum is an earth of a very peculiar nature, different from every other—an earth which is an essential ingredient in clays, and gives to them their peculiar properties of smell and ductility. Hence this earth was called "argil," from the Greek word "ἄργιλλος," meaning white, as the earth was a white powder; but Morveau afterwards gave it the name of "alumina," because it is obtained in the state of greatest purity from alum. It is got from this substance by dissolving alum in water, and pouring ammonia into the solution, when a precipitate appears; this precipitate is separated and washed, then boiled in liquid potash till the whole is dissolved: a solution of sal-ammoniac being poured into this liquid, a white flocculent matter precipitates, which, when washed and dried, is pure alumina. It has no taste, and, when pure, no smell. Its specific gravity is 2·000.

Alumina thus obtained assumes two very different appearances, according to the way in which the precipitation has been conducted. If the earthy salt be dissolved in as little water as possible, the alumina has the appearance of a white earth, light, friable, very spongy, and attaching itself strongly to the tongue. In this state Saussure distinguishes it by the name of "spongy alumina."

But if the salt has been dissolved in a great quantity of water, the alumina is obtained in a brittle, transparent, yellow-coloured mass, splitting in pieces like roll sulphur when held in the hand. Its fracture is smooth and conchoidal, it does not adhere to the

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tongue, and has not the common appearance of an earthy body. In this state Saussure gives it the name of "gelatinous alumina."

Previous discoveries led Sir Humphry Davy to consider alumina as a metallic oxide. His experiments leave little doubt on the subject, though he did not succeed in obtaining the metal in a separate state. When potassium is passed through alumina heated to whiteness, a considerable proportion of it is converted into potash, and gray metallic particles are perceived in the mass, which effervesce in water, and are converted into alumina. When a globule of iron is fused by galvanism in contact with moist alumina, it forms an alloy with aluminum. It effervesces slowly in water, being covered with a white powder. To this metallic basis Davy gave the name of aluminum.

But it is to Wöhler that we are indebted for a method of obtaining aluminum in a state of purity, and for determining its properties.

Professor Œrsted first discovered that, when dry alumina is intimately mixed with charcoal powder, and a current of dry chlorine gas is passed through the mixture while heated to redness in a porcelain tube, an anhydrous chloride of aluminum is formed. To form this chloride, the best process is to mix intimately hydrate of alumina, well washed and dried, with a quantity of charcoal powder, sugar, and oil; to make the whole up into a ball, and t beat it in a covered crucible till the sugar and oil are decomposec The black matter thus obtained is put into a porcelain tube, an a current of dry chlorine gas passed over it while heated to rec ness. The chloride of aluminum sublimes, and gradually obstructs the farther extremity of the porcelain tube. It is a solid crystalline body, having a pale greenish-yellow colour, semi-transparent, and in plates. In the air it smokes feebly, and soon deliquesces. When thrown into water it dissolves with the evolution of great heat. It is volatilized at a temperature not much higher than that of boiling water, and it fuses at a heat not very different from that at which it is volatilized. It was by decomposing this chloride that Wöhler obtained pure aluminum. His method was as follows:—

Some pieces of potassium, well freed from naphtha, are put into the bottom of a porcelain or platinum crucible, over which nearly an equal volume of chloride of aluminum is put. The lid of the crucible should be tied down with an iron wire. The crucible is now heated by a spirit lamp, at first gently, and then more briskly. The greatest quantity of potassium employed was a piece about the size of a pea. At the instant of decomposition a very violent heat is evolved, which raises the crucible instantly to redness. The matter in the crucible is fused, and of a grayish-black colour. When quite cold it is plunged into a large vessel filled with water, to remove the potash and weaken its action, so as to prevent it from acting on the aluminum. During the solution a little fetid hydrogen gas is exhaled, and there remains undissolved a gray powder, which, viewed by a microscope in the sun, appears to consist of small metallic plates. The water is drawn off, and, other water being added, the aluminum is collected on a filter, washed, and dried.

Aluminum in this state has a great resemblance to platinum. When burnished it assumes the metallic lustre and the splendour of tin. When rubbed in a mortar, the scales admit of compression, and then constitute larger scales, so that in all probability it is a malleable metal. It is not fusible at the temperature at which cast iron melts. When exposed to a strong heat, surrounded with charcoal powder, it undergoes no alteration. In powder, it is a non-conductor of electricity; but iron is also a non-conductor when in powder, as when reduced from oxalate of iron by heat. When heated to redness it takes fire, burns with extreme splendour, and is converted into alumina, which, by the violence of the heat, if the combustion be in oxygen, is fused into a button hard enough to cut glass, and almost as hard as sapphire.

It is not oxidized in water at the common temperature of the air, and water may be evaporated off aluminum without altering it: but when that liquid is raised to the boiling temperature, the aluminum begins to decompose it, and hydrogen gas is given out slowly. But this process is very slow and imperfect. At the ordinary temperature, aluminum is not attacked by concentrated sulphuric acid nor by nitric acid. But when heated it dissolves rapidly in the former of these acids, sulphurous acid being evolved. It dissolves in dilute sulphuric acid, and in muriatic acid, with the evolution of hydrogen gas. It dissolves, with the evolution of hydrogen gas, in very dilute solutions of potash, and even of ammonia, and the quantity of alumina which that alkali can dissolve in that way is very great. When heated in chlorine gas it takes fire, and is converted into chloride of aluminum.

So far as is known at present, aluminum unites with only one proportion of oxygen, and forms the base usually distinguished by the name of alumina, which is a compound of—

1 atom aluminum	1·25
1 atom oxygen	1·00
	2·25

Alumina is one of the weakest of the bases. It even seems to perform the part of an acid in certain combinations which occur in the mineral kingdom. The affinity between alumina and magnesia is very great, for the presence of alumina facilitates the precipitation of magnesia from any of its solutions by ammonia. Thus Chevenix found, that if an excess of ammonia be added to a solution of muriate of magnesia, mixed with a large proportion of muriate of alumina, nothing remained in solution but muriate of ammonia—the two earths being precipitated in combination; and their mutual affinity was even sufficient to resist the action which potash exerts on aluminous earth. By the intense heat of the gas blow-pipe, or of oxygen alone, alumina and lime may be fused together when the alumina is in excess; but alumina and magnesia will not run together at any heat, according to Kirwan and Guyton. The mutual attraction between silica and alumina is shown by an experiment of Morveau, in which, when a solution of silicate of potash and of alumina and potash are mixed, the two earths are precipitated in combination, by which the properties of each are modified. So, also, at a very intense heat, this affinity is developed by the earths entering into fusion, and forming a milky glass or enamel. Alumina unites also with some of the metallic oxides by fusion, forming enamel of different colours. Acids dissolve alumina with ease, especially when it has been recently precipitated. The salts thus formed are for the most part soluble in water, and, generally speaking, their tendency to crystallization is small. The more distant and uncommon salts are insoluble; but for the general properties of the aluminous salts we must refer to the more extended chemical systems. The triple compound in alum, or the chief salt of alumina, has been already noticed.

Alumina has never yet been obtained in a crystallized form. It has no effect whatever on vegetable colours. The most intense heat does not fuse it; but it has the singular property of diminishing in bulk in proportion to the intensity of the fire to which it is exposed. It is found native in beautiful crystals, constituting the precious stone called sapphire, one of the hardest and most beautiful of the gems; also the ruby, and the adamantine spar of corundum, are alumina nearly pure and crystallized, but have not any of the more obvious properties of clay, for, instead of being amorphous, soft, and diffusible through water, they are crystallized, are among the hardest substances in nature, and will not mix with water.

Berzelius considers alumina to be composed of—

Aluminum	53·3
Oxygen	46·7
	100·0

Hydrogen being reckoned unity, he regarded its constitution to be two atoms of aluminum, $13·716 \times 2 = 27·432$; with three atoms of oxygen, $8·013 \times 3 = 24·039$; its atomic weight is consequently 51·471. Dr. Thomson states its constitution to be, one atom of aluminum $= 10$, with one atom of oxygen $= 8$, giving 18 as its atomic weight. Brande gives the constitution of alumina as under—

Aluminum	52·94
Oxygen	47·06
	100·00

Davy reduced alumina by voltaic electricity, and by the action of potassium in vapour upon alumina heated to redness. Further attempts were made by Œrsted and Berzelius; but it was first obtained in a perfectly separate state by Wöhler in 1827, who procured it by acting with heat upon chloride of aluminum with potassium, the chlorine combining with the potassium; the chloride so formed was dissolved with water, and the aluminum was left. Aluminum thus obtained is a gray powder, resembling platina in appearance; when burnished it has the lustre of tin;

it does not fuse at the temperature of melting cast iron, and it is a non-conductor of electricity, which is also the case with iron in a finely-divided state. When heated to redness in the air it burns with great vividness, and is converted, by the acquisition of oxygen, into alumina; in pure oxygen it burns with so great splendour that the eye can scarcely support it, but in order to produce this effect it must be previously heated to redness; the heat evolved is sufficiently great to fuse the alumina partially, and it is then as hard as corundum.

Aluminum does not decompose water until it is heated to ebullition, and then decomposition is slowly effected. Neither sulphuric, muriatic, nor nitric acid dissolve aluminum when cold; but when heated they act upon it quickly. It dissolves very readily even in a weak solution of potash with the evolution of hydrogen gas; solution of ammonia also dissolves it. With oxygen, as already noticed, aluminum forms alumina; combined with chlorine, the result is a deliquescent chloride. Sulphuret of aluminum may be procured by dropping sulphur upon heated aluminum; it is a black powder, which decomposes by exposure to the air, and which, when put into water, deposits alumina and evolves sulphuretted hydrogen.

It appears probable from the experiments of Sir H. Davy, that alumina is a metallic oxide, but he was not able to extract the metallic basis by means of electro-galvanism so clearly as in the cases of lime and potass, and consequently alumina must still be considered as an analogical peroxide, of which the base is a terrigenous metal that yet wants due confirmation. The above illustrious chemist threw out the idea that all the metals have one common origin, and the different kinds that are found are modifications of the primitive formation; and that the earths are derived from the metals by oxidation, and are metallic oxides. A theory may be propounded that all the earths have one common origin, and that the kinds and varieties that occur on the face of the globe are modifications of the parent substance, and have proceeded from accidents and occasional circumstances of operation. This latter idea may seem as reasonable as the production of soils by oxidation, and more especially when the original metals are not to be seen in existence, but are found by nice artificial processes.

Clay is reckoned to be the argillaceous detritus of glaciers by those persons who have adopted that theory of the formation of the vast diluvial and alluvial deposits of unstratified formations, which lie above the uppermost regular stratification on the surface of the globe. As this theory relates to the formation, and not to the composition, of clay, it will be stated at large in the next chapter, the analogies examined, and the probabilities established or rejected.

In the natural history arrangement of mineralogy, clay, under the name of common clay, is included in the clay and lithomarge families, which have some affinity with the members of the felspar genus, and is placed immediately after it. The families have no regular form or cleavage, and cannot therefore be connected with any of the mineral species. Common clay occurs massive, dull, and feebly glimmering, when small scales of mica are present; colour yellow, grayish, greenish gray, spotted with yellow and brown; fracture coarse and small grained, uneven in the large, and in the small earthy; soils slightly; very easily frangible; sectile, and the streak slightly resinous; intermediate between friable and soft, but inclining more to the first; adheres slightly to the tongue; feels rather rough and very slightly greasy, or meagre.

This general name includes the ancient clays which built Babylon and Damascus, and is called brick-loam.

Pipe-clay is a provincial term for the aluminous bed found near Poole in Dorsetshire, and gets the name from the purpose to which it is applied. The colour is grayish-white, fracture earthy, and the feel is smooth and greasy; it adheres to the tongue, and is very plastic, tenacious, and infusible.

Potters' clay is of various colours, and disintegrates by exposure to the air; when mixed with sand, it is made into bricks and tiles. It is found in Hampshire, Berkshire, Devonshire, and is largely used in the Staffordshire potteries. The Hampshire clay yielded by analysis—

Silica	51
Alumina	25
Lime	

with some oxide of manganese and water.

This clay occurs in the secondary or fletz formations, and is a frequent mineral in alluvial districts, where it sometimes occurs in beds of considerable thickness. It is much used in potteries, in the manufacture of the different kinds of earthenware; it is also made into bricks, tiles, crucibles, and tobacco-pipes, and is employed in improving sandy and calcareous soils.

The colours white and gray, very seldom mountain green, occur massive-friable, approaching to solid; internally dull or feebly glimmering, from intermixed scales of mica; fracture in the large coarse-grained, uneven in the small, fine, earthy; more or less shining in the streak; fragments very blunt edged, opaque; soils slightly; very soft, passing into friable; sectile; adheres strongly to the tongue—more strongly than loam; feels rather greasy; becomes plastic in water; it is infusible, and contains, according to Klaproth,—

Silica	61
Alumina	27
Oxide of iron	1
Water	11
	100

Pure clay has hitherto been found only at Halle, in Saxony, where it occurs very near the surface, and accompanied by gypsum. The colour is snow white or yellowish-white, and occurs in small kidney-shaped pieces. It is without lustre; its fracture is fine, earthy; it is opaque; stains the fingers slightly; adheres feebly to the tongue; is fine, but meagre to the touch; is very light, soft, and easily frangible. It contains, by the analysis of Fourcroy—

Alumina	45
Sulphated lime	24
Water	27
Silex	4
	100

Porcelain clay forms beds in gneiss, and not unfrequently occurs in granite, occupying the place of felspar; indeed, it may be readily traced through various states of induration into true felspar, hence it has been considered as decomposed felspar, and also unformed or imperfect felspar. It is employed in the manufacture of Berlin porcelain, and is procured from the district of Magdeburg. The best French porcelain clay is dug near Limoges, of which the analysis is given below. The best English porcelain clay is procured from Cornwall, and is naturally mixed with quartz and mica, forming a granite, from both of which it is separated by washing.

The colour is reddish-white, passing to yellowish and grayish-white. It occurs in mass and disseminated. It stains the fingers; is for the most part slightly coherent, passing into dusty; is fine, but meagre to the touch; slightly adheres to the tongue, and is but of little specific gravity. According to Vauquelin, it contains—

Silica	55
Alumina	27
Oxide of iron	1
Lime	2
Water	15
	100

The colour changes to various shades of white; it is dull and opaque; occurs friable or compact; feels soft to the fingers; and adheres to the tongue. It is infusible, and its specific gravity is 2·216. The clay of Cornwall includes crystals of felspar, quartz, and mica; the porcelain manufactures of Worcester are supplied from it; and, according to Wedgwood, it consists of 60 parts of alumina and 40 of silica. It probably arises from the decomposition of felspar. The porcelain clay of China is called "kaolin;" this clay occurs in France, Saxony, and Austria. The kinds of clay depend upon the nature and composition of the rocks from the disintegration of which they have been formed: thus, slate, steatite, and trap, each yields a different kind of clay.

Stourbridge clay is of a dark colour, owing, apparently, to an admixture of carbonaceous matter. It is most extensively employed in the manufacture of crucibles, and especially for those used in glass making. It is extremely refractory in the fire. It yielded by analysis—

Silica	57·0
Alumina	30·4
Moisture	12·6
	100·0

A trace of iron and carbonaceous matter is also found. It appears to have originated from the disintegration of shale.

Indurated clay, or clay stone, has the colours of greenish-gray, bluish, ash, smoke, and pearl-gray, or brownish-red. It occurs in mass, is opaque, and without lustre. Its fracture is fine-grained, earthy, passing into slaty, splintering, and imperfectly conchoidal. It adheres but slightly to the tongue, is soft, and easily frangible.

When put into water it falls to pieces by degrees, but even then possesses very little ductility. It occurs in rock masses, in veins and beds, and forms the basis of clay porphyry. It passes, on the one hand, into potters' clay, and, on the other, into jasper.

Shale clay has the colour of smoke-gray, yellowish, ash, or bluish-gray, or grayish-black. It occurs in mass. It is dull, but when mixed with mica is glimmering. Its fracture is slaty, approaching sometimes to earthy. It is opaque, soft, and easily frangible; it is meagre to the touch, adheres slightly to the tongue; specific gravity 2·6. It occurs in the independent coal formation, also in the most recent fletz, trap, and alluvial formations. It generally breaks down when put into water, and by exposure to the weather, it decomposes into a very unctuous and tenacious clay.

Common clay, which was first mentioned, has been divided, with regard to utility, into three classes of unctuous, meagre, and calcareous. The unctuous in general contains more alumina than the meagre, and the siliceous ingredient is in finer grains when burnt; it adheres strongly to the tongue, but its texture is not visibly porous. When containing little or no oxide of iron, it burns to a very good white colour, and is very infusible; pipes are made of it, and it forms the basis of the white Staffordshire ware. If it contains oxide of iron, or pyrites, sufficient to colour it red when baked, as is usually the case, it becomes much more fusible, and can only be employed in manufacturing the coarser kinds of pottery.

Meagre clay is such as, when dry, does not take a polish from rubbing it with the nail; it feels gritty between the teeth, and the sand which it contains is in visible grains. When burnt without addition, it has a coarse granular texture, and is employed in the manufacture of bricks and tiles.

Calcareous clay effervesces with acids, is unctuous to the touch, and always contains iron enough to give it a red colour when baked. It is much more fusible than any of the preceding, and is only employed in brick-making; by judicious burning, it may be made to assume a semi-vitreous texture, and bricks thus made are very durable.

Any of the unctuous or meagre clays, that are very infusible, and contain but little iron, may be employed in making crucibles and other similar chemical vessels, that are required to stand a powerful heat.

Clay, or a soft, unctuous, tenacious earth, is found in a native state in different situations. Dr. Fordyce described the mass when mixed with water to be tenacious, hardened by drying, and not easily again diffused in water; it becomes hard when heated red-hot, burns to a brick, resembling crystalline earth in its properties. Clayey or soapy earth is found in the surface soil of most countries, and also in the mineral strata to an immense depth; it is less frequently found pure than sand, with which it is much mixed, and is more or less adulterated with other earths, and with different materials, such as mineral, vegetable, and animal substances. The purest clay contains upwards of 60 per cent. of siliceous matter, or sand, by the statement of Lord Dundonald.

Mr. Kirwan mentions clay as being of various colours, white, gray, brownish-red, brownish-black, yellow, or bluish; it feels smooth and somewhat unctuous; if moist, it adheres to the fingers, and if sufficiently so, it becomes tough and ductile; if dry, it adheres more or less to the tongue; if thrown into water, it gradually diffuses itself through it, and slowly separates from it. It does not usually effervesce with acids, unless a strong heat be applied, or when it contains a few calcareous particles, or magnesia. It consists of argil and fine sand, usually of the siliceous kind, in various proportions, and more or less ferruginous matter. The argil, according to Mr. Kirwan, forms generally from 20 to 75 per cent. of the whole mass, the sand and calx of iron the remainder. These are perfectly separable by boiling in strong vitriolic acid. He further observes, that clay in its usual state of dryness can absorb two and a half times its weight of water without suffering any to drop out, and retains it in the open air more pertinaciously than other earths. This curious circumstance, that water, as it crystallizes, detrudes the clay which is diffused in it, corresponds with other acts of congelation. Thus, when wine or vinegar, or common salt and water, are exposed to frosty air, the alcohol, the acetous acid, the marine salt, and the calx of copper, are all of them detruded from the aqueous particles, and retreat to the central part of the fluid, or to that least frozen, or into numerous cells surrounded with partitions of ice, as has been frequently observed; whence it appears, that wet clay is in general rendered more solid and tenacious by being frozen, as well as when it is dried, and its moisture exhaled by too warm a sun, both which cases are very unfriendly to vegetation. In most clays a kind of effervescence occurs, after they are turned over and thrown into heaps, and thus air enters into their interstices, which renders them much fitter for the purposes of vitrification, and forwards the processes of brick-kiln and pottery. This greater facility to vitrify is probably effected by the union of oxygen with the iron which most clays contain, as oxides of lead and manganese are used in the more perfect vitrifications. When the clay abounds with vitriolic acid, so as to be converted into alum, it becomes very unfriendly to vegetable life.

A very peculiar formation of clay has been discovered in clay-balls, called "Ludi Helmontii," from the circumstance of that celebrated physiologist having very much exercised his ingenuity in discovering and explaining the medicinal properties of the inclosures of the aluminous earth. The fossil is opaque, of an irregular shape, but of a very regular and singular internal structure. It is of an earthy hue, and always divided into separate masses by a number of veins of a different colour and purer matter than the rest. These masses, into which it is divided, are sometimes small, and pretty regularly figured, in which case they are called tali ludi, or dice; but they are more frequently of no regular shape at all. There are others of them crustated, or composed of many coats, disposed one over another about a central nucleus. In these, the "septa," or dividing veins, are very thin and fine; in the others, thicker. The septa are said to have been given with success in medicine, but are now wholly disregarded. The clay balls are found in many of the British clay strata, and are usually lodged therein with the utmost regularity, like pavement, often touching each other, as is the case with two remarkable layers of this fossil near the top of the clay on which London stands. Sometimes a small spring of water oozes out of these layers of clay balls, and the same is found to possess mineral qualities, and they have been thought to be the source of the mineral springs in the immediate vicinity of the metropolis. When exposed to the air and rain, clay balls soon split and fall into an ochre powder, and at length mix with the soil; but the spar occupying the septa is sometimes very durable, and remains entire after the substance of the ball is mouldered away. A very fine and durable cement has been manufactured from the clay balls and largely used for water-works and stuccoing of buildings. It is not certain that all the clay balls lodged in the different clay strata are exactly similar in composition, or adapted to the manufacture of cement; the analysis and trial might be worth the attention.

The chief consideration to be treated on the subject of the constitution of clay is the very distinguishing and inseparable quality of its imbibing a very large quantity of moisture, retaining it with great obstinacy, the bulk of the substance contracting by heat, and the outside being hardened by exposure. These qualities impart a very peculiar character to clay, which attaches to every designation of the substance, and to all the kinds and varieties of the aluminous earth. The properties are very much modified by the admixture of other matters, especially of loam, which, in large proportions, entirely alters the nature of the earth, and the clayey character almost wholly ceases. In this mixture of elements, caloric exerts the power of its energy, in dilating bodies, and in promoting the causes of chemical affinity. Most bodies are expanded by heat and are contracted by cold; to this general law there are a few exceptions, in which clay is included. Alumina gradually loses part of its weight when exposed to heat, owing to its parting with water. The spongy alumina parts more readily with water than the gelatinous; thus, when exposed to a red heat, the spongy loses 0·58 part of its weight, the gelatinous only 0·43. Alumina not only loses its weight, but undergoes a diminution of bulk, when exposed to heat. The contraction goes on in very high degrees of heat, but the loss in weight no longer progresses. This shows that its contraction cannot be wholly ascribed to the expulsion of its water, but may be partly owing to a change in the arrangement of its particles. Hardened or baked clay is no longer kneadable with water, though as finely pulverized as mechanical means can go. Hence it has been inferred, that clays owe their ductility to a kind of gluten, which is supposed to be dissipated by heat. They recover that property, however, by a solution in an acid and precipitation; whence it should seem to depend either on a minute portion of acid contained in clays, or the smallness of the particles when precipitated.

Caloric, or the cause of heat, is conducted through bodies in consequence of their affinity for it, and of the property which they have of combining with an indefinite application of the subtle element. Bodies vary in their power of conducting heat. The metals are the best conductors of heat of all known bodies, gold being the best and highest in the graduated scale of conductors, or 1000, and clay being the lowest, or 11·4. Clay holds much water, and that fluid is a very bad conductor of heat. The specific heat of clay has not been ascertained, but analogy may assume the lowest ratio, or that of the oxides, about 0·1356, water being 1. Thus it would require a large quantity of caloric to raise the temperature of clay to a given degree.

The ductile and baking quality of clay imparts the useful property for the manufacture of bricks and pottery, while the very same attachment produces the perplexing unfitness of the aluminous earths for the purposes of cultivation. In the first application of clay, the plastic quality produced by the large reception of water permits the moulding and forging of the earth into any shapes or forms, while the property of contracting and hardening by heat admits of the manufacture being reduced into permanent applications and durable purposes. The use of bricks is of incalculable value in the alluvial districts of country where stones are not found in rocky strata, while pottery of every kind affords one of the most elegant enjoyments of civilized society. For making bricks the best proportions are—of silica 86 parts, of alumina 14. The red colour of bricks and tiles is owing to the alteration of oxide of iron during the process of burning, the iron being further oxidized by the decomposition of the water applied to the clay in kneading. Much oxide has a tendency to vitrify the bricks, if any lime be present; and the proportions of silica and alumina also mechanically effect the character of the articles in making them too dry and rifty, and not sufficiently ductile. The quality and appearance are thus affected, both chemically and mechanically.

It has been mentioned that clay imbibes a very large quantity of moisture, and retains it with great obstinacy. In this condition the aluminous earths form a soil that is too wet and cold for the roots of vegetable life, and the mass is impenetrable to caloric, or the acting cause of heat. If it be exposed to the rays of the sun, the outside is glistened and hardened; and if the mass be broken into smaller pieces, the lumps are contracted and baked into hardness, which defies the mechanical efforts of a further reduction of bulk. Water increases very largely in volume by the effects of congelation, and when clay is exposed to the action of frost, the contained water is enlarged in bulk, and when it undergoes the alternations of freezing and thawing, the clammy texture is torn apart, the particles are sundered, and the earthy mass is heaved and burst by the action of the operations of the water that is contained. Hence the necessity of exposing clay during winter to the vicissitudes of the atmospheric elements, being the only way of reducing to pulverization the clammy and indurated texture of the aluminous formation of earths. The wet state of clay prevents any operation of culture, and the hardened condition defies every mechanical performance till the alternations of being wetted in autumn and baked in the suns of summer induce a bursting of the concretions, somewhat similar to the effects of the frosts and thaws of winter.

The rays of the sun, which is the great natural source of heat, emit three kinds of influence—the colorific, calorific, and the deoxidizing. The first changes the colour of bodies, and imparts a wholly new exterior hue; the second communicates heat to bodies, which they imbibe and retain according to their affinity for it, or according to the absolute or inherent heat of the original formation; and the third separates oxygen from the various bodies which are exposed to the influence of the sun. The power of the rays of the sun communicates no quantity of heat to the body of clay; the outside is hardened and becomes glistening, but caloric does not penetrate beyond the extreme outside. The body is one of the very worst conductors of heat: it neither receives nor retains it. The colour of clay is not altered in any sensible degree by the rays of the sun; in some cases, a colour of deep red becomes a little paler in appearance, while the black clays and the sandy and pale colours are noway changed by the strongest heats of the sun. The third influence, or the deoxidizing effect of the solar rays, separates the oxygen from the aluminous base, and thereby imparts the sweetening benefit which clay lands are known to receive from the exposure to the sun during the process of summer fallowing. An oxide is sour, but not acid, and means a combination of oxygen and some other substance destitute of the properties belonging to acids. It is very common to find the same base combine with different doses of oxygen, and form both acids and oxides. In all these cases, the smaller proportion of oxygen constitutes the oxides, and the larger the acid. Hence it follows that oxides always contain less oxygen than acids with the same base.

In the present state of chemical knowledge on the subject, clay must be reckoned an analogical peroxide of aluminum, or an oxide having a base saturated with oxygen, but not to the extent of sourness; or it may be a compound base of two atoms of base and three of oxygen, and be designated a sesquioxide. In this condition the influence of the rays of the sun is required to separate the aerial body from the metallic base, and leave the earthy residue in a milder and more pulverulent form. Oxygen is the parent of sourness, but not the condition of it, and the presence or absence of the gas will confer a quality that partakes of the gradation which the gaseous quantity holds to the containing base. The metallic bases of the alkalies and earths decompose water with great rapidity at the usual temperature of the atmosphere, and the quantity of oxygen may be thus augmented from the portion which the water contains, and render clay a sesquioxide, as before mentioned. In combination with water, clay is a hydrate, and is freed of the presence of superabundant moisture by the solar influence now mentioned.

The expansion of water by cold or congelation is very anomalous, and is productive of some important consequences considered as a natural operation. Frozen clay is expanded by the congelation of the water which it contains, and the bulk is alternately enlarged and contracted by the vicissitudes of the weather; the adhesion of the particles is thus lessened, and the viscous texture is loosened and abandoned. The expansion of water by congelation arises from a new arrangement of the particles in crystallization, and does not at all resemble the regular and gradual expansion of metals by heat, which dilates the substance by entering into and combining with the basic constituents of the formation. In the expansion of clay by the crystallized water, no combination is formed between the bodies in connection; the water returns, by being thawed, to its original state, but in thus changing conditions a very beneficial alteration is effected in the state of the clay. Clay holds fifteen times its own weight of water without dropping, and this volume of water being enlarged by congelation, an addition is made by the extra quantity contained to the natural property of crystallized expansion, which takes place in any quantity of the watery fluid. This fact forms a most important consideration in every notice of clay. In the making of bricks and porcelain, the large quantity of water confers the plastic and ductile quality which moulds into any shape or form, and which is durably hardened by the subsequent application of heat; and for the purposes of cultivation, the imbibing and retaining of so much moisture causes the bursting and crumbling of the texture of the clay, by the expansion of the congealed water in a crystallized condition. These qualities confer the value on clay for both purposes now mentioned.

The important branch of the science of chemistry which treats of heat is still very vague, even in its best-established points, and consequently, when an attempt is made to theorize, error is almost unavoidable. Though every new modification and improvement is probably an approximation, yet there is much uncertainty in chemical theory, and even an improbability of its ever being able to reach absolute certainty. But we shall endeavour to avoid error as far as is in our power by adhering closely to accurate experimental details, and pointing out, as clearly as we can, what is certain from what is still doubtful or hypothetic.

Alumina is the earth of clay, and is got in the greatest purity from alum: hence the name. Sir Humphry Davy, as before noticed, was led by his previous discoveries to consider alumina as a metallic oxide. His experiments leave little doubt on the subject, though he did not succeed in obtaining the metal in a separate state by means of galvanism. So far as is known at present, the metal proposed to be called aluminum unites with only one proportion of oxygen, and forms the base usually distinguished by the name of alumina. This powder is therefore the analogical peroxide of aluminum, or a simple base with one atom of oxygen; or it may probably be stretched by discovery into a sesquioxide, or a compound base with one atom and a half oxygen, or two base and three oxygen. Beyond these analogical probabilities, chemistry does not ascertain the composition of clay.

In its natural properties, clay may be kneaded into a very ductile paste by means of its affinity for water, and is possessed of a good deal of tenacity. This ductility is owing to the alumina it contains, and it retains water with more obstinacy than any of the other earths. By a violent heat it is baked into a hard consistence of durable forms, and in acquiring the second property it loses the first, which is only restored by solution in an acid and precipitation. It hardens and contracts by heat, and is expanded by congelation of the contained water, which is enlarged by freezing, and thus bursts the texture of the clay. As was before mentioned, the quality which forms bricks, tiles, and porcelain, confers the property that resists the mechanical powers of cultivation, and renders clay lands so very stubborn and tenacious, and in certain conditions so very unproductive. Yet the presence of clay is essential to the fertility of lands; without it soils are barren, and with a superabundance of it, the aluminous quality produces the same extreme. It is always found to be mixed with much silica, some oxide of iron, water, and sulphuric acid; and the richness of it depends on the quantity and quality of the exuvial matter it contains of animals and vegetables, and on the mode or manner in which these remains are intermixed with the primary constituents. Clay forms the base of all good lands; the absorbing and retention of moisture depends on its presence, and this quality constitutes a large reckoning in the graduated numeration of soils. These graduated qualities shall be duly entertained and estimated in the following treatise on clay lands.

CHAPTER II.

Geological Deposits of Clay.—Marine and Fresh-water Formations.

In most of the theories that have been put forth by our earth-making writers, it has been assumed as a principle that the agglutinated and hardened mineral masses which we see forming mountains, and to which we have given the name of rocks, originally formed the crust of the earth, whether they have been produced by the agency of water or of fire, and whether they have proceeded from a state of solution or of fusion; and that all the other bodies and formations, massive, detached, or reduced in form and substance, have appeared at subsequent periods, from the decomposition of the original substances by the effect of convulsions, disruptions, and of the universal deluge, to all which phenomena, by the almost universal consent of opinion, the globe has been subjected. Rocks are very considerable component parts of the earth, and are composed of certain particular mineral substances, which are resolved by chemical analysis into their proximate constituent parts, and these are further resolvable into elementary or indecomposable molecules. The appearance of organic remains that are contained in the rocks, as impressions left of life that had at one time existed, marks a very particular epoch of geology, as denoting a very distant anterior epoch of formation to the rocks of that character, and that they have proceeded from the action of a destroying fire which had pervaded and destroyed the globe, prior to the appearance of water as a distinct element. Hence the term "primitive" has been used to distinguish that formation which contains no exuviæ of organic life, and which is very much hardened and crystallized in the texture. But this opinion of different epochs of the formation of the earth is now gradually giving way to the supposition that some peculiar chemical or mechanical agency had been exerted at the time of the different formations, and that the absence or presence of organic remains does not indicate with any certainty the existence or the total want of marine or terrestrial inhabitants on the globe. Organic remains are first discovered in the felspar of soft granite, and appear in greater or less quantities in remote or adjacent situations, and reach the deposit of chalk, or the most recent stratified formation, being a loosely-aggregated carbonate of lime.

The theory of disintegration and decomposition of rocks into smaller fragments holds out, from extensive observation and long-continued experience, that by the combined influence of air and water, and of vegetable creation, rocks are decomposed, and that the hardest masses are not proof against this change, which will go on with greater or less rapidity, according to the constitution of the rocks and the power of the operating agents of disintegration. This effect is mainly produced by the absorption of water, and by its congelation and rarefaction while it was diffused within the rocky bodies. The known external causes of the entire decomposition of stony matters, are—water, carbon, and carbonic acid gas, which enter into new combinations with the saline matters, the sulphur, the ferruginous oxides, the manganese, the lime, and other constituent parts of the stones with which they come in contact. In hot climates, that produce a luxuriance of vegetation, the progress of decomposition will be rapid; in cold latitudes it will be much slower; but whether slow or rapid, all substances are liable to decomposition, and even the purest crystal is deprived, by exposure, of its fine polish and brilliant lustre, and the beginning of a coat commences. Soft or porcelain granite has been mentioned, which contains quartz, felspar, and mica. The quartz is almost pure siliceous earth in a crystallized form; felspar and mica are compound substances, and contain silica, alumina, oxide of iron, with lime, potassa, and magnesia. By exposure the lime and potassa are acted upon by water or carbonic acid, the oxide of iron tends to combine with more oxygen, and the mica and felspar are decomposed, the latter more rapidly. The felspar forms a fine clay; the mica, more partially reduced, blends with it as sand; and the harder quartz will appear as gravel or sands of different degrees of fineness. The seeds of lichens and of plants floating in the air fix themselves on the least appearance of earth, and, by the death and decomposition of the vegetation that proceeds, afford a quantity of organized matter which mixes with the earthy materials of the rock. More perfect plants succeed and perish, and add a succession of increasing material; the rock continues to decompose; and by slow and gradual processes, a soil is formed in which plants and the largest forest trees are produced.

This is the generally-received opinion of the formation of soils and alluviums from the detrition of rocks by the force of external agencies, and that the disintegrated materials have been carried by floods to the ocean, and there accumulating, are formed into horizontal layers. But the decay of rocks themselves must be very gradual; in some dry countries, inscriptions are perfect, and angular edges and shapes are little blunted or altered after the lapse of twenty centuries. The formations that are taking place in the present quiescent state of the globe are made by the sea, fresh-water rivers, and by lacustrine deposits from substances collected and rolled along by the course of the waters over the earth. These depositions go on in many places visibly, though slowly; but we know little of the processes by which the vast alluvial deposits have been made in all the different arrangements, mixtures, and combinations, to the depth of several hundred feet, and extending over vast tracks of various and discordant qualities; or of the means employed by nature in the process of alluvial deposition from the detritus accumulated at the foot of mountains from the decomposition of rocks, and of the subsequent removal and consolidation, or even of the operation by which animal and vegetable exuviæ are converted into soil. But these petrifactions and organic remains would seem sufficient to place one fact beyond dispute—that the globe has undergone many extensive changes; and it is not a little curious that they are confined to particular formations, and are not found in contiguous strata, and that the remains of trees and vegetables are found only in some few similar situations.

The different theories of the earth that have been propounded, its formation and component parts, the deposition and distribution of the very discordant and heterogeneous materials, have resolved themselves into the two very opposite extremes of fire and water having been the prime agents in the work of forming and modifying the terraqueous globe. The names applied to the theories are, the "Huttonian and Wernerian," the "Plutonic and Neptunian," and the "igneous and aqueous," which are derived from the names of the individuals who adopted and urged the opposing conceptions, the names of the heathen gods of fire and water, and the Latin appellations of the two elements of action. The Plutonists suppose that the earth has been formed from the wrecks of a former world, of which there has been a succession, and that the destruction of one has afforded materials for the composition of another; that the strata which we see forming the present globe have been formed at the bottom of the sea, and have been ejected upwards by the expansive force of heat, which has produced the very varied and irregular positions of rocks:

from horizontal they are often found vertical; from continuous, broken and separated in every possible direction; and from a plane, bent and doubled. They could not have been thus originally formed, and the power that has produced this change cannot have been inferior to that which might have been required for their elevation from the place in which they had been formed. Natural appearances confirm this reasoning, and the inference is, that the land on which we dwell has been elevated from a lower situation by the same agent which had been employed in consolidating the strata, in giving them stability, and preparing them for the purpose of the living world. This agent is, matter actuated by extreme heat, and expanded with amazing force; it has condensed the strata by means of heat, and hardened the bodies from a state of fusion. It is also a power of the same nature that has been employed in forming, by fracture and dislocation, mineral veins. By tracing the effects of volcanoes, and by a variety of other investigations, the general conclusion is deduced that all the continents and islands of this globe have been raised by means of fire above the surface of the ocean; and, therefore, that almost the whole of what we see on this earth was originally formed at the bottom of the sea. From the consideration of the materials which compose the present land, there is reason to conclude that, during the time this land was forming, by the collection of its materials at the bottom of the sea, there had been a former land containing materials similar to those which we find at present in examining the earth. It is also concluded, that there had been operations similar to those which we now find natural to the globe, and necessarily exerted in the actual formation of gravel, sand, and clay; and, moreover, that there had been in the ocean a system of animated beings, which propagated their species, and which have thus continued their respective race to this day. In order to be convinced of this truth, it is merely required to examine the strata of our earth, in which we find the remains of animals of every genus now existing in the sea, and probably every species, and perhaps some species with which we are now unacquainted. There had been also, according to this theory, a world of plants, as well as an ocean replenished with living animals.

Having ascertained the state of a former earth, in which plants and animals had lived, as well as the gradual production of the present earth composed from the materials of a former world, it is supposed that here are two operations, which are necessarily consecutive. The formation of the present earth necessarily involves the destruction of continents in the ancient world, and by pursuing in our minds the natural operations of a former earth, we clearly see the origin of that land by the fertility of which all animated bodies are fed. By the like contemplation of the present operations of the globe, there may be perceived the actual existence of those productive causes, which are now laying the foundation of land in the unfathomable regions of the sea, and which will, in time, give birth to future continents. The result of this inquiry into the succession of worlds "finds no vestige of a beginning—no prospect of an end."

This theory promulgates the idea, that all bodies have proceeded from a state of fusion, have expanded, and have been thrown into the irregular and contorted shapes by the power of heat, and have cooled by exposure. It rests both on chemical and mechanical principles, and has long formed the subject of a very keen discussion.

The Neptunian or Wernerian theory is that of water, and originated with Werner, who was Professor of Mineralogy at Freybourg, and a zealous supporter of an aqueous agency. He contends that the generally acknowledged fluidity of the globe in the primitive condition was produced, not by fire, as in the former theory, but by aqueous solution. The outlines of the system, founded on this principle, are as follow :—1. The superficial parts of the earth, to a certain depth, must have been originally in a soft or liquid state, which may be inferred from its present spheroidal shape, and from a variety of geological observations. 2. That, at the time of the creation, and for many centuries after, the interior and more central parts contained immense empty caverns, and consequently consisted of materials sufficiently solid to resist the pressure of the enormous mass of superincumbent liquid substance. 3. The materials of which the strata of the earth are composed were at one period dissolved, or suspended in water, and from this fluid they had successively consolidated in various combinations, partly by crystallization, and partly by mechanical deposition; granite, as the basis on which the greatest number of strata rest, having been first formed, and the other primitive strata in due order, by precipitations chiefly chemical. 4. From the period of the formation of these strata, the water, which covered the earth, began to decrease in height, by retiring gradually into cavities in the internal parts of the earth ; and, during this process, other precipitations were effected, and the intermediate strata, or strata of transition, were formed, of which siliceous schistus and transition are the principal. 5. When the water was still abating, the mechanical action of its mass on the strata already formed occasioned in them a partial disintegration; the materials from this source, together with the remaining part of the matter originally dissolved by their precipitation, formed the secondary strata, which are generally arranged in horizontal beds, and abundant in organic remains. 6. During the gradual consolidation of these strata, rents and cavities opened, into which the water, holding various substances in solution, retired; hence the formation of mineral veins. 7. Volcanic fires and alluviums have produced some inconsiderable and partial changes on the surface of the earth.

These two theories have nearly equally divided the world of geological inquiry; but the discussions on the subject have not led to any satisfactory conclusion. From the large number of conflicting opinions, it may be very eligibly inferred that the primary or unstratified rocks which form the basis of the globe are generally and evidently crystallized masses, often analogous to volcanic products, or compounds containing essentially minerals which are not known to be producible from water, but in several instances are obtainable from artificial heat, or generated in the deep furnaces of which volcanic mountains are the vents. Unstratified rocks generally abound along mountain chains and groups, and very often form their axis, nucleus, or centre. They seem to be derived from the depths of the earth, and to have been ejected or uplifted from below the strata, as volcanic matter is protruded at the present day. In many cases, the rocks appear as if they had been bolted upwards among other rocks, which slope away on all sides, and exhibit a broken appearance, and as if they had been rent by the violent uplifting of the protruded rocks of fusion. The second large formation, or the stratified rocks, is a composition of earthy aggregates, as sandstones, clays, or simple chemical precipitates, as limestones; such materials, in fact, as are known to be accumulated in the same mode of arrangement by modern waters. They have evidently been deposited from above successively, the lowest first, the uppermost last, in obedience to the laws of gravity. The remains of plants and animals are found in these rocks, very generally of the kinds of the present races of plants and animals that are found buried in the modern deposits of water, and which must have been in existence at the period of their formation. But the unstratified or first class of rocks contain no such evidences of watery origin or mechanical aggregation.

By all these characters, separately and comparatively considered, the two great divisions of materials which compose the external parts of our globe, are proved to have been produced by entirely opposite causes. Stratified rocks are analogous to the modern products of water, and are therefore called Neptunian, while unstratified rocks are analogous to the modern products of subterraneous fire, and receive the names of Plutonic and Volcanic, according to the degree and circumstance of this analogy. It is generally allowed, or rather it cannot be avoided, that the igneous action which produced the primary strata had preceded the aqueous agency which has stratified the succeeding deposits, and many repetitions of the Plutonic eruptions may have "primarized" the strata of all ages which happened to be nearest to the point of action. This opinion would reduce the whole materials of the earth to the condition of aqueous deposits, and that the undermost parts have been attacked and wholly altered by the violent action of a subterraneous fire, which has fused and upheaved the various and distorted forms which are seen of the crystalline rocks. The different age of the deposits loses ground in the opinions of geology—all the formations may have been made by water—the lowest rocks yet seen may be concealed by different rocks below—the most crystallized rocks may be igneous derivatives from earlier stratified deposits; and while, above, the mass of strata was augmented by additions from water, it was diminished from below by the transforming action of heat. It is safely to be admitted that igneous rocks have been in a state of fusion beneath the strata, either simultaneously or successively, in all or nearly all the parts of the globe, and that the elevation of these has been always accompanied by convulsions. The effects of general heat continually decrease among the superior strata of the earth, and seem almost wholly lost in the tertiary strata, or the depositions above the chalk.

All rocks, whether stratified or not, are naturally divided by fissures passing in different directions, independent of the strata in masses, which are of different form in dissimilar rocks, and are accompanied by circumstances deserving more attention than has yet been bestowed upon them. The fissures or planes of parting between these masses are called joints. The immediate cause of the numerous fissures of rocks is contraction after partial consolidation of the mass, as is clearly evinced in conglomerate rocks where organic remains are split by the joints, which places the fact beyond the need of argument. In these veins or fissures a different substance is often found from the rock itself, or there is contained some part of the rock in an altered condition. Granite rock admits varieties, and the name of soft is used. The exposure of that rock changes the felspar into an earthy appearance; the lustre and hardness is lost, the potash is removed, and porcelain clay is formed. The felspar and the clay differ little, as below:—

Felspar contains—		Porcelain clay contains—	
Silex	62·83	Silex	55·0
Alumina	17·02	Alumina	27·0
Lime	3·00	Oxide of iron	0·5
Oxide of iron	1·00	Water	14·0
Potash	13·00	Lime	2·0
	96·85		98·5

The clay is found in situations where decomposition is going on, or in veins inspissated along the fissures of the rock. The finest pottery ware is made of this clay, and the manufacture of porcelain is in many countries an object of very large importance. Granite is very prone to desquamations, by which degrading process the rock is broken into crusts that ultimately moulder into clay, and, along with the accompanying primary rocks of the most general and intimate association, the decomposition goes on in the depth of the deposit, without any external exposure. It is supposed that granite may have afforded the materials of all the succeeding strata of rocks of which the earth is formed, and which have proceeded from the different agencies which have prevailed over the globe. The present secondary strata are the produce of more ancient rocks, and are the immediate successors of those which are now the primary ones, as there is no reason to believe that there has been a distinct series that has entirely vanished. The proportions of the different materials in the produce ought to bear a certain relation to those in the original repositories, or if there was a difference it would be expected to be in favour of the most yielding materials, and which will be felspar, in the case of clay proceeding from the granite. But the quantity of felspar is very inconsiderable in comparison with the vast beds of clay that are found in the formation of the globe and over its surface; and consequently the inquirer is compelled to look for other agents than detrition in the formation of the alluvial and unstratified deposits. The idea is forced to begin at the lowest dawn of an earthy appearance, and to expand as the materials increase and the sphere of observation enlarges.

The above notice of clay being found in veins or small beds in soft granite and gneiss, which are the lowest associations of the primary strata, and the floor of the upper deposits, goes very far to support the theory of Werner, that water has been the chief agent in suspending and placing the stratified bodies of the globe. It is hard to conceive that fire has hardened the primary rocks below and above the soft beds of porcelain clay without interfering with that body itself, or that the rocks have cooled from a state of fusion, and have inclosed a soft body in the centre that is wholly different from the surrounding elements. If the felspar has decomposed into clay since the rocks have cooled, it is hard to think how the felspar escaped crystallization, and was left in a decomposable condition to produce the clay when the other elements are so very hardened all around it. Though water is both a chemical and mechanical agent, the productions of its power may be softer and less crystallized than the materials from fire, and the upward progress from granite to the surface of the earth discovers the most undoubted and acknowledged evidence of the gradual and total disappearance of the effects of fire, if it ever did exist to form the primary rocks. If that element be allowed the extent that has been claimed for it, it is evident that water has had a much more extensive range, and has produced much more disseminated effects.

From the porcelain clay now mentioned as the first appearance of that body, the earth of that name is seen in independent beds, but oftener interstratified with the deposits that occur in the ascending series of formations. The hardened secondary condition of clay assumes the name of schistus, or shale, the former comprehending all the varieties of slate, and the latter denoting the softer species, which crumble into earth and pass into other shapes and forms. It occurs in all the secondary formations, and ranges from the old red sandstone to the chalk. Many forms of it are found, being more or less indurated, and the colours range from gray to black, comprising also red and yellow hues of considerable variety. When highly ferruginous, it passes into argillaceous ironstone, and, becoming calcareous, into schistose marl, and into limestone. In the coal series, it often contains bitumen, or carbonaceous matter, or both, and is the frequent repository of vegetable remains, while, being interstratified with the upper limestones, it is the frequent seat of fossil shells. It seldom includes distinct fragments of other rocks; but nodules of trap have been found in some of the beds. Some varieties of shale, like others of primary argillaceous schist, contain a decomposable pyrites, and is, therefore, wrought for alum under the name of aluminous slate. The bituminous varieties are combustible. The term "shale" includes all the secondary and tertiary argillaceous schists, or the indurated clay-slate formations progressing to a softer and more earthy condition. The body, as derived from the ruins of the granite rocks, has been farther removed from the influence of subterraneous fire; has been agitated and suspended in water; and has got intermixed with other substances, in the process of deposition. This fact is evidenced by the many varieties of shale, which get the distinctive names from the qualities they are found to possess. It is thought that shale may be decomposed into clay, and clay hardened into shale, though the former opinion obtains the most credence. It is commonly interstratified in thin laminæ with the accompanying strata, to which the proportions of it are exceedingly various. The laminæ are very thin, rarely reaching to the thickness of a bed, in the proper sense of the appellation. The cases are few where shale forms an independent rock of its own substance, or rises to the aggregated bulk of a mountain or a sedimentary deposit. It is rather an association with other strata, which give to it its name and character, according to the relation and proportion which are established between the bed and the laminæ. It is evident that the proportion had not increased in the secondary strata of the formations of clay, for in the primary strata the quantity of clay-slate is large in relation to the other rocks; and, if formed from the older granite, the degradation of that rock must have been more extensive than in the case of the secondary deposits; or the whole number of primary rocks may have contributed to form the secondary strata, and thus required less materials from the granite. In that case, the shale may have proceeded from the primitive schistus by a direct operation, and indirectly from the granite.

Chemistry has not proved a real transition between clay and compact felspar, which differs from crystallized or common felspar in its chemical nature, inasmuch as it contains soda, together with potash, while common felspar contains potash alone. But the substances occur very often in the same mass, and pass into each other without definable limits. The term compact felspar may not be judicious, but an alteration without authority would be very inadvisable. The clay-stones are members of the trap family, and contain many intermediate varieties between the compact felspar and the indurated clay. The present arrangements are founded on the apparent transitions of nature, and if the supposed fact be a common or general one—that clay-stones are the produce of other rocks, there is a real transition throughout the whole of these simple rocks or bases. The chief variations of clay-stones are, the degree of induration, and the massive or schistose nature of its structure. The softest substances are found in the trap family, and the hardest pass into jasper and siliceous schist.

The first or primary clay-stone is the "argillaceous schist" of geology, which, in the order of succession, succeeds the mica slate, or the third layer from granite. It is apparent that the rock has been deposited from water, and afterwards exposed to the influence of heat, which has formed the minerals within it, and hardened the laminar texture. It shows a very considerable departure from the granular structure of granite, and a very marked progression to the earthy materials of the globe. Common felspar and compact felspar are the initiatory steps of the progression, differing from each other some what in their chemical properties, but showing a very distinct similarity in their natural appearances. From the indurated slate of the primitive formation, schist passes through many varieties and gradations, all tending to the softer consistence and easier decomposition, till, in the secondary strata of rocks, it assumes the name of shale, and accompanies, in beds or in thin laminæ, all the formations of the division of geological deposits. Primitive schistus decomposes on exposure, very readily, into clay of different degrees of tenacity, and it may be reckoned the first visible origin of cultivable clay; the other deposits are few and deeply seated—beyond the reach of use. Beds of clay occur below the trap rocks, which form an overlying cover both to the primary and secondary deposits. This fact shows that rocks are destroyed without exposure, and places clay among the foremost productions of ruin. The shales, or the schistus, or the clay-slate of the secondary strata, are associated with clays, or lie among clays, and raise a doubt whether they are being indurated or decomposed. The latter opinion prevails, in accordance with the established belief that decomposition has, in a gradual progression, produced the very numerous and varied appearances of the terraqueous globe in the first half of the meaning of the word. The shales form a large advance from the hardened primary agglutination of particles to the earthy stratum of loose materials, which constitutes the ultimate effect of disintegrating action. In some form and quality, being more fragile than schist, and wanting the continuous schistose structure, they accompany every deposit of the secondary formation, and when found above the chalk, or the last stratified deposit, they belong to the tertiary formation, and are described in the proper place. Simultaneously with the change into the softer shale of the primary indurated schistus, limestone had appeared over the lower red sandstone, and calcareous matter, very finely divided, is so abundant in many shales, as to change, locally, lias clay into an argillaceous limestone, and calcareous grit into an arenaceous limestone or coarse oolite. Before that epoch of the globe was reached, a number and variety of materials had replenished the system of nature, from whence have proceeded the complex abundance of organism and of inorganic creation which so very much perplex the inquiries, and exceed the comprehensions, of men. Clay is now seen in beds that are fit for cultivation, intermixed, interstratified, or alternated with other deposits, along with which it had been floated and suspended in the liquid element of deposition. Bitumen, alum, and sand had come into action, and these bodies are seen in an extensive connection with the earth of the decomposed schist. These mixtures will be minutely examined, and fully described under the separate heads of the peculiar formations of clay.

The strata of the globe resemble the leaves of a book, which are placed upon each other in a regular and orderly succession. The neglect of the bookbinder may omit the leaves and spoil the whole work, or he may misplace them, and render the fabric disorderly and confused. But nature commits no irregularity—strata are omitted, but the depositions are never misplaced—the beds of materials are wanting, but the place of location is invariably preserved. It is evident that there is a general analogy throughout nature in the succession, as there is in the character, of rocks; but laws of a local nature interfere, and operate many modifications in limited spots, and with much uncertainty. It is universally admitted in geology, that the globe has been exposed to very extensive ravages by the effects of water, and also that the strata of rocks, after being deposited, have been disturbed by some violent actions, which have produced upheavings, contortions, rents, and fissures, which are everywhere observed. Some theories submerge the globe wholly under water, and deposit the strata during that period of occupation. Universal formation supposes a uniform and level deposition of every stratum in a regular order, and that a definite and constant order of succession existed throughout all rocks. But, whatever identical or analogous rocks may exist extensively in many parts of the world, no one is universally continuous—the same rocks only occur in many different places, and the term "general analogies" would better express the real meaning. As the present subject relates only to Britain, the inquiry is restricted to the stratification which is seen in that island. In south Britain the stratification ascends regularly, and deposits the alluvium over the chalk, which is the uppermost stratified formation. In proceeding northwards, the beds of deposits are very much decreased, the stratification omits many formations, till at last the alluvium is deposited on the primary rocks of gneiss and granite, which form the floor of the geological staircase. In the north of Scotland the highest rock which the country contains, or the old red sandstone, lies upon the gneiss, and it supports some few patches of coal, without the intervention of the carboniferous limestone and the other accompaniments of the system. The lias and the oolite formations appear in a corner of the West Highlands of Scotland, but are so very trivial as almost to escape notice. The alluvium and the sandstone lie upon the granite and the gneiss, without the intervention of schist or wacke: in several places the schist rises to the surface, but does not form a prominent type for observation. Progressing southwards, the mica schist is very largely developed, occupying a great part of the centre of Scotland, and surrounded by troughs of the lowest sandstone. Trap rocks appear in the usual overlying position, and also in ridges and dykes. The border mountains of England and Scotland are composed of schist and wacke, and descend into softer forms from the primitive deposits of Caithness and Orkney. The sandstone lies round the bases, and the coal formations appear in the north of England. The southern stratification to the Straits of Dover exhibits the regular upward progression of all the known deposits, ending with the chalk which supports the marine tertiaries, introducing a wholly new period of the globe, both in marine and terrestrial productions. With that era a very altered system of inquiry commences, and it is very curious that, in proportion as our discoveries approach the present period of existence, more doubts are raised and perplexities increased, by reason of the greater number of materials that have appeared, and which form the sphere of observation. But by strict adherence to a continuous chain of admitted conclusions, a safe course may beadopted of steering amid the delusions of reveries and fancies.

A very curious and important inquiry arises in the geological world,—if the strata which are seen in south Britain have ever extended over the northern parts of the kingdom, and being deposited, if they have been swept away, converted into ruin, and so wholly disappeared. When mountains, rocks, and high grounds are seen not far distant from each other, with the formation to the top of the same materials, and with a hollow space intervening in which wholly different substances are deposited, an idea very naturally arises in the mind that at some former time the formation of the high ground extended over the whole space; that the intervals have been torn open by some violent energy; and that the new materials have been accumulated by a subsequent process of a more quiet operation and of a more orderly nature. This compass of operation is called "denudation," which means the making naked; in relation to the under strata of rocks being laid bare by reason of the superincumbent deposits being swept away and destroyed. The aqueous theory of the globe supposes that all strata were formed under water, and deposited under cover, that the earth was wholly submerged, and that the waters retired gradually, leaving the land bare. A very heavy pressure, attended with a tumultuous action, may be supposed to have torn open and scooped the valleys, and at the same time loosened and swept away the upper strata that are missed from the occupation of the higher positions. This denudation, or the sweeping away of entire deposits so that other strata have been exposed, is very generally admitted to have been done by the agency of sea-water, and accounts for the deposit of the marine formation of clay being found overlying the chalk or the uppermost bed of stratification. The clay, or the earth of the decomposed schistus, had been derived from other quarters of the subaqueous globe, suspended in water, and impregnated with the viscous plasticity of its nature from the elements of the marine fluid, and then located by causes of which no certainty may ever be discovered. This appearance may have happened when the globe was rendered habitable for the organs of terrestrial life, and probably long posterior to the existence of marine animals and the deposition of the secondary strata on the earthy aggregates before mentioned. Appearances tend to show that the submersion of the globe has taken place more than once; and the results now seen have been produced by repetitions of the same process, and by the same agents. During these operations the marine formations of clay have been deposited, or those beds of the aluminous earth which contain shells or spoils of the ocean, to testify the connection with the waters of the sea. These formations are found on the higher stratification of south Britain, where the current of recess would be less violent than on lower stratifications, which would be swept bare by the strong reflux of the descending waters to a lower level of position. The shells that are found in the lowest formations of clay, and to which they give the distinctive name of "marine," show an existence wholly different from the present kinds of conchoidal life, though, in many cases, the species exhibit a transition, or an approach, and even an identical sameness, to the now existing genera of shells. And these deposits, being the lowest tertiary formation, evince in these shells the commencement of the present zoological period, as do the other diluvial relics of the present animal life.

After having performed these operations on the newly-emerged surface of the globe, the waters of the sea retired to their prescribed limits, and the whole face of nature became the scene of more quiet alterations, and of more orderly performances. To the agency of marine water there had succeeded the overflowings, washings, and quiet stagnations of fresh water, which are recorded and distinguished by the names of deluges and inundations, which covered the globe wholly or partially, and to limited or indefinite heights. As in the case of sea water, a repetition of inundations may be supposed to have produced the very deep deposits of alluvium which are formed in many places which had been left hollow by the marine agency, and which afforded a ready reception to the sedimentary deposits of the fresh-water inundations. On high grounds the beds of alluvia are thin, and very often wholly disappear. The fresh-water deposits of clay lie on lower grounds, but still above the dip of the marine formations, and consequently show a more recent origin; and, having no marine shells in the body of the formation, no connection can be traced with the ocean, or the life it contained, in the animals of that period of the globe.

The alluvial strata show a much more orderly and tranquil system of operations than seem to have prevailed at former periods of the formation of the earth,—than even when subject to the immediately preceding agency of sea water, or whatever power deposited the tumultuous assemblage of diluvial relics, which are found in the utmost confusion, and huddled together, in some few places of convenient resort. The marine formations of clay are found only in the high stratification of south Britain, while the fresh-water deposits extend over the whole kingdom, mostly lying on every formation, from the primitive granite to the heterogeneous beds of unstratified diluvium, and exhibiting the most convincing proofs of comparative tranquillity, both in the preparation of the materials and in the deposition. The absence of marine shells, and the much less viscous nature of the texture, distinguish the later formed clays from the deposits of marine water. These characteristic distinctions prevail over all the formations of clay, and serve most effectually to separate the two descriptions of recognised deposits.

Clay has been called the argillaceous detritus of glaciers by those persons who have adopted the lately promulgated theory of glaciers having been the chief agent in the formation of the vast accumulations of diluvial and alluvial deposits of unstratified materials. That theory supposes the earth to have been covered, at some remote period, by huge masses of ice during a period of intense cold; that a change of temperature disrupted and moved the glaciers, which retreated to the ocean, and in their progress the valleys were torn open and scooped out by the weighty pressure and the slow power of the retreating glacier. Erratic blocks, boulders, and gravels have for some time past been attributed to the operations of glaciers in valleys, and subsequently of water; and it has been supposed that the former began, and that the latter finished, the formation, as the parent block of boulders, pebbles, and gravels is generally found at the head of each valley, and consequently could not have been washed in by currents, as the distribution of the materials diverges from the great central chains of the country that follow the course of the valleys. It is supposed that the polished and striated surface of rocks and blocks proceeds from the effects of glaciers, and from the contact of moving masses of ice, and that the formations of clays, gravel, and mud deposits, and of stratified fossiliferous accumulations, have derived the materials from masses of ice, and have been rearranged by water produced by the melting of the glaciers. This supposition appears to account for the great mammifers that are found in the polar ice, and in the so-called diluvial formations.

The large polished blocks found in tills and in stratified gravels may be supposed to have been produced by similar causes, as is constantly shown in the detritus found in the bottoms of alpine valleys. The terraces or table-lands, forming equal altitudes on opposite declivities, are supposed to be accumulations of blocks and pebbles on the flanks and terminations of the glaciers which occupied and formed the valleys, and to have been successively deposited by the melting of the ice. Though differently deposited, and presenting a double talus of ridge, one to the glacier and another to the wall of rock flanking the valley, the origin is evidently common with the accumulation of pebbles and of blocks polished and rounded under great masses of ice, and afterwards rearranged by water. The marked differences of the arrangement of the materials in the deposits is supposed to arise from the different action to which they have been exposed; large and small fragments falling on the glaciers have been deposited promiscuously, while in the valleys the finer part is generally on the top, from having undergone the action of ice and water. Uniform polish of rocks in "situ" is produced by ice, and the striated form by the interposition of substances which produce "striæ," agreeing with the direction of the moving mass, while the effects of water are sinuous erosions on the softer materials of rocks. The finer materials being found at the greatest distance from mountains, is thought to support the theory of glaciers retreating from the valleys, as the blocks and detritus are larger as we approach elevated regions, and also that the triturating action of sheets of ice has formed the vast group of clays, gravels, and pebbles. But a great difficulty occurs in forming the connection between stratified fossiliferous deposits and the glacier detritus, and in accounting for the remains of arctic animals being found in the clays superimposed on the till, and therefore posterior to the glacier epoch. This theory of glaciers forms a part of the great problem of geology: it would appear to account for the disappearance of the organic beings of the diluvial period, and also for the disappearance of the great mammifers inclosed in the polar ice; it is associated with the elevation of the alpine countries and the dispersion of erratic blocks; and it is also intimately mixed up with the subject of a general diminution of the terrestrial heat. But much extensive observation, and a profound acquaintance with facts, will be required to establish from that theory any of the so-called certainties of geology.

The above-written theory of glacial agency may possibly be admitted to have performed some part of alluvial deposition, in grinding rocks to pulverization by the heavy weight of the triturating action of the moving masses of ice, by which the finer parts became clay, and the coarser parts were formed into gravel. It would suppose a frozen mass to have moved from the higher grounds to the sea, and to have produced a very large quantity of water, which operated on the upper alluvial formations after the disappearance of the glaciers by the melting of the ice. Then it is hard to comprehend how the deposited materials should differ so very much in closely contiguous situations, and where the original substances exhibit little or no primary divarication. A very large sphere of operation must be allowed to the agency of water in a subsequent period of the alterations on the face of the globe, for the very various qualities and discordant quantities could not have resulted from the single process of the melting of the glaciers, but rather from the varied and repeated performances of distant periods of agency. This conclusion seems inevitable; for the glaciers would not contain the shells of sea animals that are found in the marine formation of clay, nor could the melted water impart the very viscous tenacity of texture which is possessed by the aluminous beds of that denomination. Neither could the single performance of a retreating and melting body of ice, however gradually and leisurely done in every stage of the operations, commence and finish the depositions that are found in beds of various qualities and thickness, loose and firm, incompact and concreted. A succession and a repetition of agencies of different qualities and powers must have been employed to produce the vast accumulations that are heaped together, sometimes in close contiguity, and oftener in distant localities, but still showing evidence of the same relations of existence, and the same sources of production. Water must be allowed the place of the chief agent, whether proceeding from the marine collection, the inundations of fresh water, or from the melting of glaciers. No conclusive theory has yet advanced beyond this generally received opinion on the subject.

The era of the Noachian deluge is most usually assigned as the period of the alluvial depositions on the globe. This epoch may be received in the case of the uppermost formations of the loams and soft earths, which occur in the bottoms of valleys, and over the flat grounds of estuary levels. In these productions, the feeble texture may be allowed to show a more recent construction and a less potent agency than the more concreted formations of clay, which are certainly not stratified, but many are laminar, and show the relics of a schistose structure. These deposits are the most allied to the shales that were before described, lie deepest among the rocky formations, and constitute a link in the chain of progress from the argillaceous schistus to the best amalgamated deposits of clay. Consequently the materials may have been less exposed to the agency of water of any kind, and may have been placed in a firm position before the period of the universal deluge. This general inundation may have only smoothed the surface without disturbing the deposits, and gathered, in its passage over the formations, some materials with which to impart a nature similar, but weaker, to the new alluvial aggregations that were formed of heterogeneous substances. In this way the more mixed nature of the upper clays, their weaker texture, and generally their better quality for use, is accounted for.

It is evident that the upper clays, or the most recent formations, have been subjected to very different agencies from the first beds of that nature which occur in the softer rocks of decomposition. In many places the denuding powers of water had swept from the original position the huge masses of strata, which were again replaced in positions of tranquillity in a very altered form, after having received from the watery element constitutional qualities that were before unknown, and being dispossessed of the original properties of their nature. This is the general result of physical agencies; and though water is not a violent operator, yet its continued action has produced many altered forms and discordant qualities, in most instances of an intimate exposure. The aluminous plasticity has not been expelled, but very much modified; and the whole texture bears the marks of a washing or ablution in a lenient menstruum, which has, by the continuance of slender efforts, reduced the viscous adhesiveness and conferred a milder tenacity. The shales of the secondary strata of deposits are impregnated with alum, bitumen, and other substances that approximate to carbon and lignite; and when decomposed into clay by the agency of water, these elements bestow the distinctive character on the earthy formation. The general inundation had not penetrated the beds of these deposits that were deeply seated before the time of its occurrence, and the primitive nature of the substances would remain unchanged. So far there are evidently different periods of convulsion.

The powerful agency of an agitated fluid in a state of retrocession must be recognised in every consideration of the form of any large portion of the surface of the earth, or of reflection upon the nature and disposition of its alluvial tracts. The course and moulding force of its vast and extensive power are everywhere betrayed by the abrupt and curved outlines; the fractured sinuosities of glens, defiles, and valleys; the salient and re-entrant angles; and even by the plains, which seem to terminate the labours of nature's agony in the throes of production. The gradual degradation produced by the influence of the atmosphere and the current of streams, seems to be wholly inadequate to produce such effects. In whatever way the solid crust of the globe has been formed, or however numerous may have been the agents made use of in producing it—whether its existence be due to Plutonian or Neptunian action, or to agencies yet undiscovered or unknown—every diluvial fact, or every certain demonstration about the chalk, concurs in denoting one inundation which overwhelmed the solid mass of the globe; and unless we admit that that inundation was not only universal, but that it was the last catastrophe to which the earth has been exposed, it is impossible to explain those phenomena which have been already ascertained, and which are daily occurring to observation.

Very widely extended deposits of clay are found lying on strata that are wholly different from the argillaceous type, and which, from that circumstance, exhibit a very strong proof of the agency of some transporting power in arranging the upper materials of the globe. These formations of clay have been attributed to the detrition of rocks which had been placed in these situations, and which have entirely disappeared from view. This theory has been obscurely and rather hiddenly developed, and has not been much handled; it shows an effort to account for appearances from entirely unobserved causes, and begins a course that cannot be admitted into a legitimate train of reasoning. The supposition of unknown powers of agency producing results from existing materials, seems not to be denied in any speculative inquiry; but the notion is very different respecting ideal materials, on which known or supposed actions are allowed the exertions of their power, and in such a degree as altogether to banish existence. It would account for some few thin deposits in which the elements are not very discordant, and may be allowed to alter the complexion of the formation where the visible elements are very different. But the general application must be very vague and unsatisfactory, and it has only been used for some level inland districts where the diluvial beds are not found, and the alluvium is not very abundant. Scarcely more than the one case has been mentioned of the rich dark brown soils of Scotland, where, in the central districts, the agency of water would have less extent of operation than in valleys along the sides of rivers, and by the mouths of estuaries, where the flux and reflux of the fluid would have an uncontrolled access. The soil resembles the decomposition of trap rocks or ancient lavas, and, by a stretch of theory, similar substances are thought to have existed to produce the analogy of materials. But such reasoning often leads to the most fallacious results.

Clay has thus been traced step by step from the first appearance as veins or thin beds in the rocks of soft granite and gneiss, in the gradual ascent to the terminating deposits left by sea and fresh water on the face of the globe. The first decompositions are done without exposure, and caused by the universal law of natural decay, or the tendency of substances to change state or condition. The rocks, in ascending from the granite, quickly assume the schistose structure, or the formation of slates or thin cleavages. The fourth rock from the granite is called the argillaceous or clayey schistus, as it moulders into the earth that has got and preserved that appellation. From this rock, which is not an extremely hardened primary formation, have been derived the materials that form the shales of the secondary strata, which express the condition of the schistus in a softer state, and are found to be impregnated with other substances that had now come into existence. These shales or schistose aggregates decompose into the earths of clay which compose the first exhibitions of the aluminous bodies that are reduced to cultivable utility. The succeeding denudations and inundations which have swept and overwhelmed the face of the globe, have collected materials from these formations of the argillaceous type; have washed and cleansed the substances; have transported the accumulations to various places; and located the deposits upon principles concerning which no certainty can ever be arrived at. A closely traceable connection is thus formed through every gradation of the ascending series of deposits.

The shales form by far the most important part of observation in the consecutive formations of clay. They appear in association with the old red sandstone, which forms the base of the carboniferous system, and the first rock that relaxes from the hardness of the primary crystallization. The shale of that sandstone deposit is found in a fissile and tenacious condition, and serves for roofing-slate and flags. In the coal series the strata are large, lying above the deposit of carbonized matters, the clay is hardened into a stony consistence, and so much impregnated with bitumen that it becomes somewhat like a coal. The shale, being calcined, emits an acid, which unites itself to the argillaceous earth of the shale, and forms alum; the aspect and hardness vary much, and the clays are equally various, containing argillaceous iron-stone in such large quantities as to form the principal supply of ore for the iron foundries. The coal and the accompanying strata contain pyrites, and with the galena and blende in the ironstone form the not unfrequent cause of spontaneous combustion. A conglomerated structure everywhere throughout nature accompanies a new order in rocks, which is very abundantly visible with the commencement of the carboniferous series of deposits. The clay schist assumes the name of shale, and is found intermixed with many substances which had appeared in the new formation of rocks. The ascending series of coal, from the primary anthracite to the lignite and peat of the alluvial deposition, everywhere confers qualities that are inimical to vegetation, and hence all the clays that are in direct association with the carbonized matters and mineral oils are of very inferior quality. The slate clay or shale of the coal measures differs from clay-slate by its less solid and indurated state, and is known by different names, as black or blue metal, shale, clunch, cleft, bind, &c. Shale is sometimes restricted to a variety of schistus, or the bituminous and aluminous slaty structures; but it is much more economically used to comprehend every formation of clay that is found above the old red sandstone, which forms the base of the carboniferous series of deposits. Every succeeding formation has its accompanying shale, or clay that attended its decomposition, and which is found to derive its character very much from the chief ingredients of the formation, which are always found incorporated in its substance in a greater or less degree. Hence the quality of clay is ever to be observed from the associations of its formation; the primitive schistus is much more advanced in cultivable quality than the shales of the carboniferous deposits, which are impregnated with bitumen, and are associated with the continuous progression of that noxious element. The clays found interstratified with the secondary deposits are of a repulsive quality as regards vegetation, and very much inferior to the primitive decompositions, and to the formations of clay that have happened above the chalk. In the first case the noxious elements had not appeared, and in the second were absent, and supplied with other agencies.

In some places the shales of the secondary series form very extensive strata, and rise into ranges of hills and mountains, as in Derbyshire and in the Orkney Islands of Scotland. The surface of the strata is of a softer and more shivery texture than the shale which lies deeper. It wastes by its strong acid the ore of lead, and corrodes and destroys all minerals near it except iron or coal, of whose vitriol it partakes. In the sandstone series of Caithness and Orkney shale forms two parts of a common deposit; in the latter situation many extensive tracts of shale occur, covering a great surface, and reaching to so great a depth, uninterrupted by sandstone, as to be computed at the thickness of 700 or 800 ft. There it occupies a conspicuous place among the secondary strata, and claims the rank of an independent rock. The features are invariably tame. The few hills are rounded and unmarked by protruding rocks or abrupt declivities, and often as flat as the sea which surrounds them. Yet some few abrupt vertical cliffs are as durable as the sandstones of the same position. The texture and composition of shale point it out as the parent of deep and fertile soils; but the conglomerated mixtures of the secondary strata are so varied and abundant, that an integral quality can seldom or never be found. In the era of these deposits acids and salts had come into an active abundance, and entered into very extensive combinations. It is on this account that the shales require so much accurate investigation, as affording, in a majority of cases, the elemental composition of the clays of future description.

CHAPTER III.

Clays from the Shale.—Lias Clay.—Clunch Clay.—Kimmeridge Clay.—Cultivation of each Soil.—Rotations of Cropping.—Manures, Draining, and Value of the Land.

THE sub-aërial deposit of the finely pulverized fresh-water alluvium forms the uppermost stratum on the face of the globe, and is constituted of terrestrial elements with the exuviæ of organic life. From this platform of the upper story of the terraqueous building, a ladder, placed in the usual slanting direction, conducts the inquirer to the floor of the globe, which is formed of primitive granite, and the descent leads through all the intervening formations—diluvial, secondary, and transition. But a ladder affords too quick a passage through the maze of creation, and an insufficient time is granted to satisfy curiosity, and to verify the ascertained facts. A staircase is much more eligible, which in its windings visits a larger extent of space for observation and inquiry; and during the ascent, landing and resting places are sometimes formed which afford the leisure of thought and reflection. In ascending this staircase, the passage leads through all the deposits, and finds the first cultivable argillaceous stratum in the

LIAS CLAY,

which forms the basis of the oolitic deposit of limestone, and lies on the variegated or the second formation of sandstone. The word is the "liȝ, liȝaꞅ, v liaꞅ" of the Anglo-Saxons, meaning flames, as the formation is often very bituminous, so as to induce the belief of coal, and the iron pyrites which is very abundant by its decomposition and action on the argillaceous strata, produces an efflorescence of the aluminous sulphate so extensively wrought at Whitby; to the same cause must be ascribed the spontaneous inflammation often observed in the cliffs near Charmouth, Dorsetshire, Ansted gives the derivation from a provincial corruption of the word "layers," in allusion to the laminar slices of the formation both in a rocky and earthy condition. This clay is the shale of the lowest oolitic deposit of limestone, or the argillaceous accompaniment of every formation that has happened above the old red sandstone, which marks the transition from a crystallized condition to an earthy state of the composition of the globe. The lias constitutes the basis on which the whole oolitic series reposes, and its specific gravity may have procured it the lower position of the deposit by the watery fluid. The clay is more than usually schistose in structure, and calcareous matter in very minute particles is abundantly intermixed, as to form thin beds of limestone that are separated by narrow argillaceous partings; the quarries of the rock assume at a distance a striped and riband-like appearance; the limestone beds towards their centre, where most free from external mixture, contain more than 90 per cent. of carbonate of lime; the residuum has never been distinctly analyzed, but appears to consist of alumina and iron, and in some varieties traces of silex have been found. Towards the edges of the beds, however, where they come in contact with the alternating strata of clay, the proportion of alumina is, as might be expected, more considerable. This limestone is particularly characterised by its dull earthy aspect, and large conchoidal fracture; in colour it varies, in different beds, from light slate blue or smoke gray to white; the former varieties usually constituting the upper, the latter the lower, portions of the formation. The blue lias, which contains much iron, affords a strong lime, distinguished by its property of setting under water; the white lias takes a high polish, and may readily be employed for the purposes of lithography. The slate-clay with which the lias alternates is gray, brown, or black; is frequently bituminous; and readily divides into laminæ as thin as common pasteboard. The clays of the lias deposit are more or less laminated, and include in the lower parts layers and nodules of generally argillaceous limestone, and in the upper bands and strata, ferruginous, calcareous, and arenaceous, which strongly resemble the bottom of the lower oolite formation. A partial graduated mixture has taken place during the deposition, and been prepared by the sedimentary precipitation of the clay from the lime.

The lias is not rich in earthy or metallic minerals: layers and masses of jet are frequent in it, especially in the northern part of its course, and iron seems to be the only metallic substance, which occurs in layers under the form of clay ironstone, or disseminated through the mass in the form of pyrites, but never constitutes a mineral vein. Galena and blende are said to occur in it near Bath and Whitby, sulphate of barytes near Gloucester, and sulphate of strontian at Watchet. Chert is abundant, both in the lower and upper limestones, yet siliceous matter is rare in the formation of clay, though it is seen in South Wales, where its fossil, the gryphus, is coated with chalcedony; but chert occurs in the lias of Watchet, and the lias contains veins of chert also near Cowbridge in South Wales.

The organic remains contained in the lias are peculiarly interesting, and afford a rich field for observation; the animals of a higher order, the vertebral class, are in greater number than is exhibited in the list of any other formation. Two very remarkable extinct genera of oviparous quadrupeds, evidently belonging to the same class with the great natural order *Lacerta* or lizards, are found in the argillaceous bed, to which has been given the name of *Marine Lacerta.* They appear to hold the same place with regard to recent *Lacertæ*, that the Cetacea do to other mammalia, and form a division of the order *Lacerta.* The investigation of their comparative anatomy has laid open various new and interesting links in the chain of animated nature, forming the connection of the fishes and the mammalia, as being vertebrated and provided with legs, which latter appendages form a large step in the advance of creation. Bones and palates of the turtle have been found in this formation, and fish of several species also occur in its strata, but are of extinct genera. Leech-like teeth have been found, and also those of the shark. The existence of the crocodile is doubted, but is not improbable. Crab-fish occur in one or two species. The testaceous mollusca are very numerous, both univalve and bivalve. The vegetable remains are of fossil wood occasionally silicified, and several species of ferns and flags.

The lias formation has been designated as marking the reptile period of the globe, and forming a large advance in the scale of organized life. Though the genera are extinct, they are shown to have existed, and may have been somewhere preserved, again to appear in a somewhat altered form when the earth had undergone the prescribed revolutions to suit the changes of life. The alum shale of Yorkshire belongs to the lias formation, which affords the manufactory of alum at Whitby, and bitumen appears so largely with the deposit as to have induced several trials for coal. A general tendency to an argillaceous type belongs even to the limestones of the lias formation, and the clays exhibit a schistose structure that is not so much observed in the preceding geological formations. This circumstance shows the derivation of the deposit from the "schist" of the older formations, and that the changes of the materials had not been sufficient to remove the ancient structure. These peculiarities continue till the attention is directed to the strata above the chalk, when solid layers of any kind wholly disappear, and the materials are blended in the most reduced form and irregular deposition.

The lias formation stretches across the breadth of England from the coasts of the German Ocean in Yorkshire to those of the Channel in Dorsetshire. The northern limit commences in lining the coast, and underlying the mountains of the eastern moorlands, from the Peak alum-works of Whitby nearly to the Tees mouth; sand and sandstone compose the moorlands, and probably belong to the inferior oolite. Southwards from the mouth of the Tees, the lias ranges beneath the west escarpment of the eastern moorlands, passes York on the east, and crosses the Humber a little eastward of the junction of Trent and Ouse, stretching onwards beneath the scarp of the low oolite range of Lincolnshire to the Wold Hills of Nottingham and Leicester, and the celebrated quarries of Barton-upon-Soar, whence it continues, still regularly accompanying the scarp of the hills formed by the inferior and great oolite, through the counties of Nottingham, Warwick, and Gloucester. The average breadth is about six miles, bounded on the south-east by the oolites, and on the north-west by the red marl. From within a few miles south of Gloucester, the eastern limit still continues to accompany the oolitic ranges through Somersetshire to the coast of Dorsetshire, being its line of junction with the superior formations; its western limit becomes very irregular, feathering in and out among the coal fields which occur towards the estuary of the Severn, and the upper part of the Bristol Channel in Gloucestershire, Somersetshire, Monmouthshire, and Glamorganshire, and attended by numerous outlying masses. Leaving these intricate districts, the lias advances regularly to the south, and beneath the oolitic ranges through the south-east of Somersetshire into Dorsetshire, where the overlying strata of green sand cover and conceal it, forming the high ranges of the Blackdown Hills. The sands in this quarter extend successively over the edges of all the inferior strata as far as the red marl. The lias is laid bare by denudation in all the eastern valley of the chain of sandhills, and may thus be traced to the coast of the channel, where, in the neighbourhood of Lyme, it is displayed in a range of cliffs extending about four miles, and sinking at length beneath a covering of the inferior oolite and its sand. The stratum is best examined in the cliffs of Whitby in Yorkshire, at Westbury, in the estuary of the Severn in Gloucestershire, at Watchet in Somersetshire, at Aberthaw in Glamorganshire, and at Lyme in Dorsetshire.

The lias formation generally constitutes broad and level plains at the foot of the oolitic chain of hills. Argillaceous formations mostly occur in low tracks in the present configuration of the earth's surface—a circumstance which may be attributed to their having offered less resistance to the denuding causes which modified the inequalities of that surface, than to anything connected with their original formation. The lias is seen to occupy a considerable portion of the slope of the oolitic escarpments, and in the midland counties particularly, owing to the action of currents of water, detached portions of oolite crown the summits of many insulated masses of the upper lias shales. The plains of the lias are sometimes diversified with low ridges, and a slight escarpment may often be traced following the lower limit of the formation. This escarpment is most conspicuous on the borders of Nottinghamshire and Leicestershire, where it forms a well-marked range, distinguished by the name of the Wold Hills. Near the Mendips the lias sometimes occurs on the brow of tolerably steep escarpments, but its maximum of elevation probably falls short of 500 ft. above the level of the sea.

The thickness of the beds in the midland connties is taken as between 400 and 500 ft., from the joint consideration of the dip of the beds that constitute the formation and their horizontal extent, together with the relative levels of its superior and inferior limit. The inclination of the strata is very small, not exceeding 40 ft. in the mile, and is in a south-easterly direction, conformably with all the strata ranging through the island from north-east to south-west; but it is occasionally much disturbed and affected by the ridges of mountain limestone and older rocks in Glamorganshire and Somersetshire. But such disturbances are always partial and limited, and the general character of horizontal stratification always prevails. Near Watchet these disturbances produce an appearance of alternation in the strata of lias and red rock marl.

The water in springs is generally thrown out by the marl above the lias, near its junction with the lower beds of sand underlying the inferior oolites, and it is therefore doubtful to which of the formations they should, with most propriety, be referred. Several mineral waters, as at Bath and Cheltenham, are thus situated. When completely within the district of the lias marls, water, excepting the ground springs, is only to be procured by sinking to the bottom beds.

The lias formation of clay exhibits a surface ground of cultivation in Dorsetshire, commencing at Lyme Regis, and extending into Somersetshire, by passing under the unconformable sands of Blackdown. Insulated masses of green sand frequently cover the lower oolite and lias, and render it difficult to trace the lines of junction or extent. In Somersetshire it surrounds the irregular elevations of carboniferous limestone, and advances regularly beneath the oolitic ranges through the south-east part of the county, where it enters from Dorsetshire. The vale or low ground of Gloucestershire is formed by the lias clay, and also the vale of Belvoir, in the county of Rutland, where the lias is separated from the great oolite by the red or reddish-brown ferruginous sands;

and these are covered by vast accumulations of transported gravel, near their junction with the lias, just on the western border of the county. The lias occupies the eastern side of the county of Leicester, and skirts the valley of the Soar at the distance of two or three miles eastward from that river. The eastern and south-eastern border of the county of Nottingham is chiefly occupied by the lias, which is connected with Belvoir by the west of the river Smite. In Lincolnshire, the strata of lias occupy the intervening valleys between Grantham and Newark. The eastern side is conterminous with the oolite formations, from beneath which the lias crops out; it pervades nearly all the western side of the county, advances to Lincoln, and hence to the Humber, where it terminates in a space of two or three miles in width. In Yorkshire the lias forms the aluminous shales of Whitby before mentioned, and also the base of the lofty cliffs of Staithes, supports the high moorlands of the carbonaceous sandstones and shales, and continues to the south under the Wold Hills. Not much surface-ground occurs for cultivation. In Warwickshire the formation of lias is large, extending over a great part of the county from Aldminster to Upton and Stretton-on-Dunsmore, and forms a range of high ground from Bath Hill to Dunsmore Heath. The lias caps several hills to the north-west of the Avon, and between Stratford and Henley-in-Arden. The valley of the Stour and the vale of the Red Horse are occupied by beds of the lias formation, and are frequently referred to in agricultural works. In the county of Worcester the lias formation is found at Pershore and Evesham, and in the vales watered by the Avon; it extends from Fisher's Green to the limits of the county near Tewkesbury. In the county of Glamorgan, in South Wales, the lias is extended in the formations among the dislocations of the old red sandstone, as on the opposite side of the Severn among the coal fields of Somerset and Gloucester. The vale of the river Ely, which is on the old red sandstone, divides a double chain of mountain-limestone, and the valley exhibits several lower ranges formed by up-fillings of lias, commencing about five miles west of Llandaff, whence, with some interruptions, they accompany the Ely to its junction with the channel near Penarth Point. It again appears in Barry Island, and continues to skirt the coast in a westerly direction for fifteen miles to the mouth of the Ogmore River, forming a range of bold cliffs, among which is the little harbour of Aberthaw, celebrated for the lime it exports, which has the peculiar property of setting under water. These cliffs stand directly opposite those of Watchet, on the Somerset coast.

As the oolite rests upon the sandstone which overlies the coal, the lias, being the base of the formation, becomes very much entangled among the coal basins of South Gloucester, North Somerset, and the Forest of Dean. The lias and the subjacent horizontal beds are seen filling up, near Bristol, and between that city and Bath, the interior of the basin that is formed by the strata of the encircling mountain-limestone and old red sandstone, which are raised into bold and precipitous ranges of hills, among which the strata of the coal measures are often highly inclined. Beyond the edge of the coal basins, the beds are seen at Pyrton and Aust passages, and numerous other points along the estuary of the Severn, by which the first coal fields are separated from that of the Forest of Dean. The interior of this coal basin is throughout too elevated to admit any filling up of lias ; but that rock is to be found abutting in horizontal strata against the southern edge of its exterior ridges in Gloucestershire near the mouth of the Wye, and in Monmouthshire on the south-east of Newport, also at Godcliffe on the Bristol Channel.

The lias formation of clay affords a soil that is well adapted for pasturage, in which state the greater part of that kind of land is retained. The natural herbage is not of the richest quality, and ranks much behind that of the clayey loams of Market Harborough, and the alluvial pastures of Lincolnshire. But the pasturage is thought to tend much to the formation of curd, and the name of "cheesy ground" has got a currency in the language of the dairyman, as expressive of its value in that respect. The herbage tends to softness and flaccidity, suits pasturage rather than hay, and it wants the rigidity of the upland, as well as the luxuriant richness of the lowland qualities. The pasture is the first quality of the second grade of grass lands.

The occurrence of the lias clay in an arable condition is not frequent, and the value in cultivation falls below the condition of grass, as the ground of best quality is generally kept in pasture. The soil can be ploughed by swing ploughs of a strong construction, and best by the strength of three or four horses in the winter furrow, and by two horses during the summer operations of fallowing the land, which is imperatively necessary to prepare the land for future crops. Root plants are wholly inadmissible. In most cases, but not in every instance, the land can be moved in the spring to admit of some preparation for the crop of beans ; the furrows are reversed, the soil is wrought by the alternate operations of the grubber lengthwise and across, and drills are formed, 27 in. apart, by a single furrow of the common plough ; the beans are sown by machine, or by hand, and the drills are harrowed to a level over the dung (if any) that was spread in the hollows of the ridglets. Horse-hoeing and hand-hoeing are thus most fully admitted. Where the texture of the soil does not allow the movement of the land in the spring, the surface is deeply and severely harrowed, across which ruts are made by one-horse ribbing ploughs, in which the beans grow in drills that admit of hand-hoeing, and the work of a narrow horse scarifier. Rotations are here given :—

1st year . .	Fallow.	Or—1st year . . .	Fallow.
2nd " . .	Wheat or oats.	2nd " . . .	Oats.
3rd " . .	Clover.	3rd " . . .	Beans.
4th " . .	Beans.	4th " . . .	Wheat.
5th " . .	Wheat.	5th " . . .	Clover.
		6th " . . .	Oats.

In the pasturage fashion:—

1st year	Fallow.	6th year	Beans.
2nd „	Wheat.	7th „	Wheat.
3rd „	Clover.	Or—	
4th „	Pasture.	5th year	Beans.
5th „	Oats.	6th „	Wheat.

Oats are not profitable on meagre clays; the plant requires a strong loamy adhesiveness, attended with a large openness of texture. The crop is often inserted for the sake of variation. Peas are excluded by the strong clamminess of the soil, and the failure of the crop renders the land foul with weeds, almost beyond redemption.

The quantity of lime applied to an acre of fallow land should not be under 200 bushels, and used along with farm-yard dung, which is the sole manure that the land admits to impart any benefit. The draining may be at intervals of five yards, the gutters cut and filled as before directed in the draining of clays. The grass seeds to be sown for pasture are as under, for an acre of ground:—

Ray grass . . .	½ bushel.	Dogstail . . .	4 lbs.
Cocksfoot . . .	¼ „	Red clover . . .	6 or 8 lbs.
Meadow fescue .	4 lbs.	White clover . .	4 lbs.
Meadow catstail .	4 „		

These seeds, being very intimately mixed, must be sown by a broad-cast machine on a finely-harrowed surface of ground, that is again harrowed to cover the seeds, and finished by a heavy rolling.

The lias clay is best seen in its characteristic state in the country between Bath and Bristol, where it is found in narrow valleys and not very wide extents of flat ground, and is very much interlaced among the disturbances of the underlying coal formations, and the surrounding ranges of the carboniferous limestone and old red sandstone. The clayey strata constitute the "fillings-up" of the Wernerians, by which the hollows occasioned by the irregular eminences and angular elevations of the rocky strata have been filled, and comparatively reduced to a level, by means of an earthy shale that has been reduced by an aqueous agency to the state of decomposed and plastic materials. In that locality, the rock of the lower oolite is well exhibited in the sandstone of Bath, which rests upon the lias, and supports the upper deposit of the same formation. The northern direction of the oolitic series of strata exhibits throughout the whole course a regular tendency to modifications and alterations of the attending argillaceous deposit; the quality of the clay is better in the midland counties; and in Yorkshire, where the formation terminates, its nature is wholly changed into an aluminous shale. The gault is similarly changed from the type of Surrey in the red sands of Reigate and Bletchingley, when it is found at the bottom of the chalk hills of Cambridge and Huntingdon. The denudations have been dissimilar, and the subsequent inundations have effected different purposes. The London clay varies when placed beyond the basin of the metropolis, and the plastic formation loses the primitive quality beyond the chalk range of the Northern Downs. Each formation enjoys the choice locality of its inherent type, and beyond it a variety of causes has concurred to change its nature, and at last annihilate its existence. This fact attends the particular consideration of every cultivable stratum in Britain.

The ascent of the geological staircase finds the next landing place on the platform of the

Clunch Clay,

which occupies the moist valleys of the middle deposition of the oolitic rocks. That vast argillo-arenaceo-calcareous mass is divided into three systems—the lower, middle, and upper, and each is attended by concomitant beds of argillo-calcareous, and calcareo-siliceous deposits, which divide the systems by their intermediate positions, and all the formations have characteristic local distinctions in their organic remains. The low vales occupied by the clays, which intervene between the rocks of the several deposits, have undoubtedly been caused, at least in part, by the erosive action of water; but, to whatever extent this principle is applied in explaining the present inequality of the earth's surface, and whatever aid is received for the established data of local elevation, these limited agencies always leave unexplained the general fact, viz., the regular altitude of continuous ranges of hills with uniformly declining planes, and no particular marks of convulsion, which overlook extensive undisturbed plains of older strata.

The clunch clay derives the name from the "clunches," or the indurated lumps of clay, which are found in the beds of the argillaceous mass, and which, being frequently bituminous, resemble the lumps which miners find next the coal, and have named by the above term. The formation is very deep, of a tenacious and adhesive clay, of a dark blue colour, becoming brown on exposure, and containing argillo-calcareous geodes and septaria, and some layers of a chocolate-coloured shale. The septaria, from an obvious analogy, are frequently termed turtle stones, and the geodes are employed as coarse marble. The argillaceous strata are frequently mixed with calcareous, and sometimes with bituminous matter, affording in the latter case an inflammable shale, which in varieties constitutes the origin of the clay. The lower part of the formation occasionally contains irregular beds of limestone, which, from their partial occurrence, can only be considered as subordinate to it. These have been noticed at Kelloway Bridge, near Chippenham in Wiltshire, and hence have been called the Kelloway rock. This stone occurs in irregular concretions, the exterior aspect of which is brown and sandy, the interior being harder, and of a bluish colour. It consists almost entirely of a congeries of organic remains, among which several varieties of ammonites are predominant. The beds of clay which immediately cover this rock abound in selenite, and below it are found a brown aluminous earth and bituminous wood. Beds of clay separate the Kelloway rock from the oolites of the next division. In Yorkshire the clay is less tough and more generally laminated, gradually changing in quality to the Kelloway rock below, and the calcareous grit above. The limestone is only used for mending the roads, and, as there are very few excavations for this purpose, it is difficult to trace its course; they occur chiefly in Wiltshire, and at one place in Somersetshire.

Iron pyrites and selenite occur abundantly in this clay, as in all argillaceous formations. The association of sulphur with the clay strata leads to the inquiry whether mineral waters are derived from the beds immediately contiguous to the Kelloway rock.

The organic remains differ from the lias in the bones of oviparous quadrupeds. They are rare, and show an entirely different species. The shells are both univalve and bivalve, chambered and not chambered. The limestone is distinguished by peculiar bivalves, which do not occur in the clay.

The depth of the clunch clay is ascertained to reach 700 ft. in the midland counties, and cannot be much less in the south-western. The general dip of the formation appears to be to the east and south-east under an angle scarcely, if at all, exceeding one degree, except in the elevated tract north of Weymouth, where the direction and dip change, and the angle is often as high as 30 degrees.

Water is found by sinking through the whole formation. The work is laborious, and often unsuccessful. Mineral springs occur in the course of the formation of clay; but, perhaps, their true seat is the upper bed of the subjacent oolites. The stratum is for the most part extremely low, and the eminences are nowhere considerable. Valleys contain the greater part of the deposit.

The uncertainty which yet prevails concerning the true divisions of the oolitic formations which appear in Yorkshire, prevents the absolute decision concerning the course of this formation at the north-eastern termination of the diagonal zone which it forms across the country. It seems certain, however, that the clay occurs on the coast of that county, near Filey Bridge, underlying the calcareous grit of the coral rag formation; and it probably forms the greater part of the vale lying along the Yorkshire Derwent, as far as New Malton, and intervening between the chalk and oolite hills. On the coast of New Malton, the chalk advances close to the oolite hills, and overlies the argillaceous tract.

South of the Humber the clunch clay is traced in a southern direction, through Lincolnshire, following the course of the Ancholme navigation and the Witham river, to Boston. The formation is very narrow in the north, and becomes wider as it proceeds southward, until it disappears beneath the vast alluvium of the fens. It forms the substratum of the western portion of the Cambridgeshire fens, and those which border on Huntingdonshire. Hence it has been called "Fen clay." Its breadth near the Humber is three miles, east of Lincoln about fifteen miles, and between Sleaford and Spilsby twenty-five miles; but in this part it is partially covered by the marshes of the Witham. It occupies the valley of the Ouse through Bedfordshire, and a large extent in the county of Huntingdon, which forms the separation between the middle and lower assemblage of oolites. The position is nearly horizontal, and the depth has been ascertained as 500 to 700 ft. From Bedford to Oxford the breadth is about five or six miles, and often less. West of Oxford it occupies the valley of the Isis as far as Cricklade, crops out from beneath the coral rag, and occupies the middle part of the county as far as Bicester, Woodstock, Witney, and Bampton, near which towns the line of junction between this and the subjacent formations may be traced. From this large extent the argillaceous deposit has been called "Oxford clay," and the tract of country is for the most part low and flat. In Buckinghamshire the clunch clay rises from under the Aylesbury limestone, and extends to the town of Buckingham, and to the north-west of Stony Stratford and Newport Pagnell. From Cricklade the clay bends to the east of Malmsbury, traverses Wilts in a south direction, following the course of the Avon, past Chippenham, to Melksham, having a breadth of from five to eight miles, and being always bounded by the escarpment of the coral rag on the south and east, and by the rise of the hills formed by the subjacent oolites on the north and west. From Melksham its course continues south, through Somersetshire and Dorsetshire, passing by Wincanton and Sturminster, on the south of which it is overlaid by the great western extension of the chalk and green sand. In this part of its course it is not more than three miles across, and has always the subjacent oolites on the west and the coral rag escarpment on the east, except near Wincanton, where the green sand advances upon this formation.

The formation reappears in the south of Dorsetshire, in the Weymouth denudation, where its course is sufficiently indicated by that of the coral rag, since it occurs interposed between the central nucleus of the subjacent oolites and the collateral chains of that rock.

The chief development of the clunch clay is in Oxfordshire, and in the county of Lincoln, where, along with some few other localities, the surface ground is reduced to arable purposes. The general character is a cold and intractable clay, not so favourable to grass as the lias formation, and little or no better in its quality for the production of crops. It exhibits more proofs of the indurated shale of the "schist," which forms the type of the argillaceous deposits, and the composition is less bituminous and coaly, as being a step farther removed from the carboniferous formations. The texture excludes green crops, and is not favourable to the proper cultivation of beans. But in many cases, or mostly in all, the land can be moved in the spring in preparation for the crop of beans, which are sown in drills of 27 in. apart to admit the horse hoe. The work is done by the grubber lengthwise and crosswise, after one ploughing from the winter furrow, when the drills are opened by the common plough, the dung deposited, the seeds sown, and the drills reversed by the same implement. When the adhesive quality of the soil does not admit any movement of the land in the spring, the surface is deeply and severely harrowed across the winter ploughing, on which ruts are opened by one-horse ploughs to receive the seeds, or the beans are deposited by the drill machines that are provided with long coulters which make ruts in the ground, and the work is covered by a bush harrow. Where the land is of good quality, and free from weeds, the dung may be laid on the stubble in the late autumn or early winter, and ploughed into the ground by the winter furrow. The surface is harrowed in the spring, and drilled across, as before directed.

The rotations will be best in cropping as under:—

1st year . .	Fallow, dung and lime.	4th year .	Oats or wheat.
2nd „ . .	Wheat.	5th „ . .	Clover.
3rd „ . .	Beans.	6th „ . .	Oats.

And—

1st year. .	Fallow, dung and lime.	4th year .	Oats.
2nd „ . .	Wheat.	5th „ . .	Beans.
3rd „ . .	Clover.	6th „ . .	Wheat.

Or—

1st year	Fallow.	4th year	Wheat.
2nd „	Oats.	5th „	Clover.
3rd „	Beans.	6th „	Oats.

The pasturage system will be—

1st year	Fallow.	5th year	Oats.
2nd „	Wheat.	6th „	Beans.
3rd „	Clover.	7th „	Wheat.
4th „	Pasture.		

Farm-yard dung is the only manure that is admissible, except the usual pulverised top-dressing on the spring crops, and the quantity of lime applied to the bare fallow should not be under 150 bushels an acre, and done in every third return of the rotation. The draining to be performed with an interval of five or six yards between the cavities, placed and filled as before directed. The seeds of grasses to be sown for pasture are as under:—

	Per Acre.		Per Acre.
Ray grass	½ bushel.	Dogstail	4 lbs.
Cocksfoot	¼ „	Red clover	8 „
Meadow fescue .	4 lbs.	White clover. . . .	4 „
Catstail	4 „		

Clay lands should be ploughed in November or December, with a furrow of seven or eight inches in depth, by five or six inches in width. The subsequent ploughings may be done by two horses, and the furrows must be narrow, so that no land remain unmoved. A strong close-tined grubber may be very beneficially introduced in one or two operations during the latter workings of the land: the soil will be loosened which may adhere in the plough furrow, and the texture will be rendered more porous. For completing this purpose two grubbings are required, singly, in the longitudinal and cross directions, by which both the ploughing and harrowing of the ground are very much assisted. The due and careful performance of the process of fallowing, lays the foundation of the value of every crop in the rotation. The wheat rests on the depth of the cultivation, the clover depends on the pulverization of the surface, and the oats on the incipient adhesion of the moved and sliced soil.

At no very great distance from the clunch clay, in the ascent of the geological staircase, the observing inquirer finds another argillaceous deposit, called

Kimmeridge Clay,

which gets its name from Kimmeridge, the place in the Isle of Purbeck where the beds of the shale are seen in the cliffs of the coast, and also on the coast of the Isle of Portland. On the east of Little Kimmeridge the cliffs are abrupt, and composed of a slate-clay, of a grayish yellow colour, finely slaty, containing both animal and vegetable remains. The plates of which the rock is composed become much more evident after it has undergone some decay; or, when sound, after it has been exposed to the fire. It divides spontaneously into large tabular masses. The fracture of the rock is earthy, with many small specks and nodules of indurated clay. The outside of the rock is covered by a thin layer of calcareous spar. The mass effervesces with acids, but the nodules of indurated clay do not. This rock passes gradually into a bituminous shale, but the first transition is into a slate clay of a lighter or darker colour, the joints of which are covered with iron pyrites. It burns with a yellowish flame, giving out a sulphurous smell, and becomes afterwards of a light gray colour. The second transition is to a bituminous shale, called "Stony coal" (Kimmeridge clay), the specific gravity of which is 1·319. Its colour is dark brown, without any lustre; it effervesces slightly with acids, contains no iron pyrites, and burns readily with a yellowish, rather smoky, and heavy flame. The smell is bituminous, but not sulphurous. The Kimmeridge coal rests upon, and is covered by, the slate-clay first described.

The beds of blue slaty or grayish yellow clay contain selenite and layers of highly bituminous shale, which are used as fuel, and hence the name of Kimmeridge coal, which is applied to the whole formation, including the clay. It has been sometimes erroneously supposed that these beds were the same with the aluminous shale of Whitby, in Yorkshire, which belongs to the lias beds. These beds contain the selenites of Oxfordshire, which are daily formed by the action of decomposing pyrites upon the oyster shells and other fossils contained in them. Alum was formerly manufactured in the parish of Kimmeridge.

The organic remains are chiefly of extinct genera of Lacertæ, evidently calculated for a marine abode. The quadrupedal species differ from those of the lias, and bones, apparently of the "Cetacea," likewise occur. The shells are numerous. Univalve, chambered and not chambered, and many bivalve.

The positions of the Kimmeridge clays are overlooked by the rocks of the upper oolite formation, which has the most commanding appearance in Portland Isle, in the vale of Pewsey, at Swindon, and in the vale of Aylesbury. The clay occupies a tract in Wiltshire, rarely exceeding two miles in breadth, but extending in length from the Berkshire border to west of Devizes, beyond which it is covered by the westward extension of the overlying formations. At Swindon beds of oolitic freestone divide beds of clay that are not well defined, and probably the Kimmeridge bed it is that occupies the vale of Wardour, and extends into Dorsetshire. In that county the formation runs in a narrow vale. In the counties of Berks and Buckingham, the Kimmeridge clay is seen in the few appearances of the upper oolite formation, and is often wanting, the clunch clay supporting the Portland beds. In Lincolnshire it passes beneath the Wolds, and occupies the north side of the vale of Pickering, in Yorkshire, where it passes into the Speeton clay above. The Kimmeridge clay forms the substratum of the whole Isle of Portland, and rises high on its northern face, where it is capped by an abrupt escarpment of the superior oolitic beds. All the strata sensibly decline, though not under a very rapid angle, to the south, bringing the line of junction between the clay and the oolite to the level of the sea. All the coasts of the island are steep, the base of Kimmeridge clay forming a sloping talus, surmounted by crags of the oolite, scarred by numerous quarries.

In the Isle of Purbeck, the depth of 700 ft. has been assigned to the Kimmeridge clay, but it seems excessive. Dr. Buckland states 600. Near Oxford, where the beds thin off, the thickness cannot exceed 100 ft. In the pit at Lumingwell, near Bagley Wood, it was only 70 ft., as ascertained from boring for coal. In the vale of White Horse, and at Swindon, it was penetrated by a well to the depth of 233 ft., and the additional thickness of the incumbent beds on the hills being taken at only 70 ft., the stratum will appear 300 ft. thick. In Lincolnshire and in Yorkshire, its thickness generally appears much less, through the unconformity of the chalk strata. The water in this formation is deficient and of bad quality, and from its retentive nature, it must generally be pierced through before any copious supply can be found. The Kimmeridge clay is nearly horizontal, dipping in an almost inappreciable angle south-south-east. Immediately on the south of Abingdon, the clay pursues its course westwards through the vale of Berkshire, following the line of the Berks and Wilts Canal as far as Wootton Basset, where it turns more to the south, and ranges on the east of Calne and of Seend, reposing all the way on the inner edge of the coral rag. Near the latter place the chalk and subjacent green sand overlie and conceal it, advancing in a sort of projecting cape even into the district of the great oolite. In the above interval of country, the Portland bed of stone only once appears reposing on the clay, being concealed by the alluvial débris, or overlaid and hidden by the superior strata.

The typical character of the Kimmeridge clay is a blue slaty substance, with selenite, sometimes highly bituminous, being a thick clay deposit, forming a cold, stiff soil, in broad vales, and without springs. The quality of the surface ground is inferior both to the clunch and lias clays, either for arable purposes or in pasturage ; the herbage tends to sourness, and the texture is very clammy and repulsive to the tender growth of plants. The summer fallowing of the land is imperatively necessary, as the root crops are completely excluded, and the soil requires an ample manuring of farm-yard dung, along with lime, to lay the foundation of the following crops. These two substances are the only articles which the soil will suffer to act upon it as a fertilizer. Though beans may be used as an occasional crop, and probably with advantage, yet it does not hold a creditable position in the rotations of cropping on the Kimmeridge clays. The plant requires a viscous loaminess in the soil in which it grows with advantage, and the certain degree of loamy adhesiveness is not often found, and most certainly does not exist, in the formation of clay that is now under consideration. Unless the quality of the soil freely admits some preparation of the land in the spring, and the drilling and complete horse and hand hoeing of the beans, the crop is much better omitted, for the plant in broad-cast never fails to fill the land with abundance of weeds, which, being perfected in the seeds by the late harvesting of the beans, add a profusion of the germs of future vegetation to perplex and encumber the cleaning of the ground. On the inferior clay lands of any denomination, beans are better omitted, and the grazing fashion adopted. Thus :—

1st year . .	Fallow, dung and lime in 150 bushels.	3rd year	Clover.
		4th „	Pasture.
		5th „	Pasture.
2nd „ . . .	Wheat.	6th „	Oats.

In the case of beans being used—

1st year	Fallow.	4th year . .	Pasture.
2nd „	Wheat.	5th „ . .	Beans.
3rd „	Clover.	6th „ . .	Wheat or oats.

Barley might be tried on the summer fallow of the land, and will succeed with good working of the soil, ample manuring, and a dose of lime in the proportion of 150 bushels to an acre. Peas are inadmissible, but vetches, both in the winter and spring varieties, may be used thus :—

1st year	Fallow.	Or—	
2nd „	Wheat.	4th year	Pasture.
3rd „	Clover.	5th „	Vetches.
4th „	Oats.	6th „	Oats.
5th „	Vetches.	7th „	Beans.
6th „	Wheat.	8th „	Wheat.

The first rotation, or the pasturing scheme, is decidedly the most preferable, and the necessary grasses are specified below :—

Ray grass, per acre	½ bushel.	Hand fescue . . .	2 lbs.
Cocksfoot . . .	¼ „	Fieldbrome . . .	2 „
Meadow fescue .	4 lbs.	Red clover . . .	6 „
Catstail	4 „	White clover . .	4 „
Dogstail	4 „		

The draining of the Kimmeridge clays requires a frequency of five or six yards in the position of the drains, and the depth and filling with materials to be as before described.

The oolitic series of deposits, which comprehends the three kinds of clay that have been described, has been allowed a depth of 3000 ft., consisting in strata of calcareous, arenaceous, and argillaceous materials, associated in several rather similar groups of three terms each—clay, sandstone, and limestone. The organic remains of the whole system are somewhat similar, yet differing in each group and in each term of the groups. It contains a very heterogeneous mass of substances that have been derived from pre-existing materials, and which are arranged in a very evident connection with the saliferous system below, and the cretaceous system which covers the deposit. Clays and shells predominate in the formation, and through all the mass of materials the most remarkable repetitions occur. The clays, to which our business chiefly relates, evince the true existence of the shale, and are found to be aluminous, bituminous, and indurated, as formerly mentioned under the respective heads. The whole deposit has evidently proceeded from the mechanical agency of water, while the parallelism of beds over large regions, the repetition of similar rocks at frequent intervals, and the gradual change of the species of organic remains through the whole series, appear to indicate that the long period when the oölitic system was deposited was one in which the ordinary operations of nature were uninterrupted by any paroxysm of igneous violence. The beds are seldom or never unconformed to others of the same system below them; the deposition may be hidden by the sand or the chalk, and yet there may be no unconformity. The sand adheres very much to the calcareous matter, and forms the concretionary structure of the oolite deposit, and from hardened building stones, the aggregations pass into shelly and rubbly layers of loose materials, forming the soils of the cornbrash and coral rag, so called from the constituents of their formation. These loose layers form the top of the oolite deposits, and pass by a gradulated assimilation to the third sandstone formation, which overlies the whole series of oolites. The clays, or the accompanying shale of each deposit, lies at the bottom of each group, having fallen, in obedience to the laws of specific gravity, to the lowest position in the liquid element which prepared the materials. In the lowest or lias formation, the constitution is very aluminous, and affords by manufacture the mineral of alum; the second deposit, or the clunch clay, is more earthy and calcareous, and lies in massy indurations; and the third layer, or Kimmeridge clay, is very bituminous, and the shale tends to the nature of coal. In the three clays, as well as in the three rocks, of the oolitic strata, very essential differences exist, each exhibiting a difference of materials, a variation of structure, and a dissimilar collection of organic remains. Yet the general appearances are sufficiently connected and analogous to justify the arrangement of being grouped together, and examined in the relative conjunction. All the formations have characteristic local distinctions in their organic remains, and many of the individual rocks, or masses of analogous beds and layers, contain particular characteristic fossils, which never or rarely occur in other rocks. The fossils of strata the most similar in their mineral nature,—as the oolitic rocks, the sandstones, and the clays,—are more frequently similar or identical than those of rocks differing in their nature. The same or similar shells are found in the lias, clunch, and Kimmeridge clays.

The clays that are extracted from the rocky depositions, where they have been formed by decomposition in the natural decay of the soft ingredients, are wholly different in nature from the formations now described. The texture is much more lenient in the adhesion, and does not possess the viscous clamminess and waxy plasticity of the clays of the oolites, and of the deposits that overlie the chalk. These formations have evidently proceeded from the agency of sea-water, and extend from the lias, or the base of the oolitic deposits, to the fresh-water formation of the Wealden clay, which constitutes the last succession of the oolitic system. In this interval are found the lias, clunch, and Kimmeridge clays, the gault or golt intervening, the upper sandstone which supports the chalk, and the plastic and London clays that overlie the cretaceous system. The nature of these clays everywhere betrays a similar descent; the minerals and organic remains differ, but many are still the same, and serve to uphold the connection. Above the chalk the agitation of the watery elements has been more extreme; the materials are reduced below the resemblance of any rock or shale, and exhibit less fixed relations with any solidified bodies. There is almost nothing in common—contemporaneous differences are carried to an extreme, and local diversities overcome all general agreement. In the older marine deposits, all these parts can be paralleled; but there is a greater analogy of contemporaneous effects, a more decided and real relation of the phenomena to time, and more proof of the sequence of effects being due to successive general changes of physical condition, which continually alter the original aspect of nature, and tend to diversify the uniformity and complicate the simplicity of the primeval state of the globe. The oolitic series, the upper sandstone, and the superincumbent chalk, follow each other in a very regular conformity, and show no violent disturbance from the effects of eruptions or igneous explosions. These disturbances seem to have ceased with the saliferous system, at least in a very great degree. The oolite graduates into the upper sand, which passes into the chalk above; but no gradation or alternation is known between the cretaceous and the tertiary deposits, which are not even conformable to each other. It is thought that the general condition of the globe hardened with the chalk in certain relations, and that a totally new arrangement had commenced, which is called the tertiary system; but the arrangement had still employed the same agents and materials, which had continued till the gradual contraction of the seas had elevated the extents of dry land. Thus the green sand and chalk exhibit an interior band to the oolites, which mark the gradual uprising of the land.

From the shale or slaty clays of the oolite series, the aspect rises to the tertiary deposits, which exhibit the bodies in a less firm condition, but still frequently laminated and mixed with very irregularly alternating beds of sands and gravels. The marine clays are exclusively confined to the cretaceous system, and appear to have been deposited on the chalk, which has been swept over the top by an overwhelming fresh-water inundation. The level surface of the argillaceous deposits having offered less resistance to the torrents than other formations, may account for the tranquil appearance of deposition which they exhibit, and may seem to sustain the opinion that the gradual elevation of the land contracted the extent of the seas, and caused the retreat of the waters to their present limits, and settled the boundaries as now observed, after the flux and reflux of many turbulent and violent motions had produced the estuary formations and valley deposits which are observed in accessible localities.

The detached calcareous materials of the oolitic deposit form separate masses of various forms and qualities. The lower bed of calcareous grit lies on the sandstone, and is often confounded with it; it is itself a thick stratum of sand inclosing irregular beds of sandstone, or of calcareous grit which assumes the aspect of coarse limestone. These sandstones are brown externally, but gray or blue within. Irregular layers of clay occur in places, and friable beds of decomposed shells. The grits are imperfectly formed rocks, and are composed of calcareous matter placed in a cement of argillaceous sand. The formations abound among and below the clays of the oolites, which on the upper parts exhibit the dry rubbly limestones of cornbrash, stonebrash, and the coral rag. The adhesive clay had sunk to the lower positions in each successive operation of similar causes, and left the top of each deposit to the drier and lighter materials. The oolitic series is the great repository of the best architectural materials which Britain produces, and the relations of its several members are very important in showing the regular and gradual transition from a subaqueous to an elevated condition of the globe, the appearance of land animals mixed with the inhabitants of the ocean, and the presence and mixture of the varied materials which constitute the present state of the earth. The clays exhibit the first earthy deposit from the decomposed rocky schist; they were produced by the agency of marine water, which conferred upon them the peculiar qualities of their nature. The same agency continued above the chalk till the elevation of the land narrowed the extent of the sea, and gave place to the alluvial operations.

CHAPTER IV.

Marine Tertiary Formations of Clay.—Plastic Clay.—London Clay.—Argillaceous Golt.—Cultivation of each Soil.—Rotations of Cropping.—Manures, Draining, and Value of the Lands.

THE ascent of the geological staircase reaches the next formation of clay lying upon the chalk, which is the uppermost regularly-stratified deposit that covers the globe. It is most generally allowed that a tumultuous marine agency had continued to disturb the face of the globe after the deposition of the chalk, and after making many extensive alterations, and forming new depositions, had given place to inundations of fresh water, which had produced the uppermost formations that are generally called alluvial. The formations that lie next to the chalk show marks of sea agency in shells and remains of fishes, and are hence called the marine formations of the tertiary system, which comprehends all the deposits above the chalk. Our description begins with the first over the chalk, which is called

Plastic Clay,

consisting in an indefinite number of sand, clay, and pebble beds, irregularly alternating. The name was conferred by Cuvier and Brongniart, who discovered an analogous deposit overlying the chalk in the neighbourhood of Paris. It consists of two beds separated by a bed of sand, the lowest bed being the plastic clay. It is unctuous, tenacious, contains siliceous but no calcareous matter, and is very refractory in the fire. In England the sands of the deposit are of an almost infinite variety of colours, and sometimes pass into sandstone. The clays, also, are of various colours and degrees of purity, and are sometimes laminated, passing into fire-clay. An argillaceous rock appears as one of the beds on the coast of Sussex. The mineral contents do not appear as veins, but are generally intermixed with the clays and sands of which the formation consists. Coal is, however, uniformly found in parallel layers or beds above and below the sands and clays. The coal is very imperfect, and recent vegetable pyrites, green earth, and nodules of a dark-coloured limestone, selenite, and fibrous gypsum, and also mica and tubular ironstone, are found in the alternating plastic beds. The organic remains show the teeth of fish, fossil bones, the branches and leaves of plants, and also more or less of the woody fibre in the vegetable coal. The occurrence of organic remains is as irregular as the alternation of the strata—being found in the clay, then in the sand, and often wanting in them all. The same barrenness is found in the analogous plastic clays of France.

The plastic and London clays are very much allied in their nature and composition; the localities are analogous, and the beds conformable. A just inference may be deduced, that the formations are identical, and have proceeded from a succession of the same agents, which have been subjected to modified actions that have produced the varied depositions that are observed. The organic remains of the plastic clay are the most strictly marine; the London deposit shows a mixture that contains an advance to the present animal and vegetable forms of life, while in the overlying formation of Bagshot sands the evidences are fewer and much more faint, and exhibit the expiring efforts of the general agent. The plastic or undermost clay may have proceeded from a turbulent and disturbed state of operations; the London clay has been deposited by a more orderly and quiet movement of action, as is very evident from the massive deposition; while the lighter sands have floated uppermost, and contain the smallest evidence of the general nature.

The deposit of plastic clay is visible overlying the concave area of the chalk which forms the London basin, and for the most part skirts the whole district occupied by the London clay, beneath which the formation lies. Thin beds of it cover the chalk hills of Surrey, at Addington and Croydon, Banstead Downs and Epsom, Ashstead and Leatherhead. Both on the north and south sides of the North Downs it dips under the London clay, which to the south is bounded by the rocky escarpment of the iron sandstone. In Sussex the plastic clay is the foundation of the flat maritime district south of the Downs, which extends from near Worthing to Bracklesham Bay, and thence into Hampshire, forming part of the Isle of Wight basin. It is seen from Arundel to the western extremity of Brighthelmstone, at which place it terminates, except an outlying portion of it occupying the summit of the chalk cliff on each side of Newhaven Harbour. Passing to the south of Salisbury, it runs into Hampshire, and thence into Dorsetshire. In the former county it underlies the London clay on which Portsmouth and Lymington are built, and which occupies a large area surrounding them. It skirts the London or blue clay in the basin of the Isle of Wight, except near Kingsclere, where, for a short distance, the chalk marl and green sand crop out from beneath the chalk. The country west of the Avon, and a belt varying from three to seven miles south of the chalk, are occupied by the plastic clay. In Dorsetshire the eastern parts of the county are covered by the plastic clay as far as Cranbourne, Chalbury, Wimbourne Minster, and the Trough of Poole. At the latter place potters' clay, in beds of various thickness, alternates with loose sand in the plastic formation. It is sent to Staffordshire and used for pottery. Beneath lies a friable brown coal, which crumbles in water, and emits a weak flame. Pipe-clay skirts the declivity of the chalk downs, and the plastic clay caps one or two hills on the south-west of Dorchester. In Wiltshire a few outlying masses of plastic clay run south of a line from Hungerford to Marlborough. The formation occupies the district between the estuary of the Thames and the range of chalk hills in Kent; it skirts the foot of the chalk hills by Farnborough and Chatham, and thence by Milton and Ospringe, where dividing, the branches skirt the London clay to Whitstable on the coast, and to Canterbury, which stands upon it, and to the coast of the Reculver; and by the south-west to Sandwich, which is built upon it, and ends a little to the south of Deal. The plastic and London clays are much mixed in the county of Essex; the latter prevails, and the former skirts the district of the London clay in the north-west of the county, terminating at Hadleigh, which is the most northerly point of the formation. Halsted and Coggleshall, with the intervening tract, are both on the plastic clay; Enfield Chace, in Middlesex, is occupied by the plastic clay, with a strip along the western boundary by Harefield and Uxbridge. In Hertfordshire, the clay of this designation extends from the Essex border at

Sawbridgeworth and Bishop Stortford, to the north of Ware, Hertford, and Hatfield, to St. Alban's, and from thence along the valley of the Colne it skirts the London clay to Uxbridge. On the north of this place it takes a westerly direction to a little on the north of Beaconsfield in Buckinghamshire, and thence about south to the banks of the Thames. It is seen again at Reading, in Berkshire, and extends thence, though not in a straight line, to a few miles beyond Hungerford, which may be said to be its extreme point on the west, except at Marlborough in Wiltshire, as before mentioned.

The formation of plastic clay that has now been traced in its extent is confined to the south-eastern part of the chalk district of south Britain, and is very much modified in quality when it approaches the oolite formations and the alluvial depositions of Essex. The extent is not great, as the largest breadth, between Houghton Hill and Dorchester, averages about eight miles, and there is a considerable tract on the west of Poole Harbour termed the Trough of Poole. The general appearances are narrow, being out-crops from beneath the London clay, and between it and the closely adjoining overlying strata of sands and loams. The surface of the formation is most generally flat, on the north-east of London remarkably so; but is more elevated on the north and north-west, as on the south-west of Hertford. Gentle eminences are seen near Deptford in Kent. In Sussex the country occupied by it is flat and even low, but towards Dorchester the surface is more undulating; and at Salisbury and Ringwood there are ranges of considerable eminence. The depth of the bed is not great: in Hertfordshire, about 100 to 120 ft.; in Middlesex, 100 to 200 ft.; round Woolwich and near London, 104 ft. The vertical cliffs of plastic clay at Alum Bay, in the Isle of Wight, are no less than 1100 ft. thick: but considerable expansion may have taken place by pressure from the vertical position, which, considering the loose state of the sandy beds, can hardly have failed to be the case. The dip of the beds is conformable with that of the chalk on which they lie; gently to the west, near Newhaven, in Sussex. Horizontal is the general direction.

The deposit of plastic clay in irregularly alternating beds of sands and pebbles with the chief ingredient, shows a very tumultuary disturbance of the materials of the globe, and a most disorderly location, which may have succeeded the quiet arrangement and the tranquil deposit of the stratified chalk on which the tertiary formation rests. The eddying reflux of the waters of the sea, in retiring over the face of the globe to the prescribed limits, may have found an abundant variety of materials, which have been carried about and located by conflicting causes that have produced the irregularities, according as the different actions found the opportunity of development. The beds are not thick nor widely spread; the marine clays and the superincumbent sands are wholly confined to the chalk formation, and more particularly to the eastern ranges of that deposit in Britain. The immediate proximity to the chalk, or the last stratified marine deposit, suggests the idea of the plastic clay having been long floated in the ocean, from which it has acquired the very extreme viscous tenacity of texture which in the ascending series of aluminous bodies becomes gradually more lenient, till it altogether disappears in the fresh-water formations. There is no appearance of decomposing shale in the plastic formation of clay; it is a tertiary deposit, from which rocks have mostly disappeared, and being the first formation, the materials had less time to become aggregated, and were puddled in a very minute reduction. The shales had accompanied the secondary deposits, but do not ascend above the chalk, where the tumultuous agency of waters had not allowed the regularity of stratified subsidence. Hence the varied confusion of the deposits above the chalk, and the very much increased uncertainty of approximating causes.

The plastic clay presents a surface ground for cultivation that is by far the most obdurate and intractable that is found in Britain. The viscous tenacity is extreme, and binds the whole mass into large lumps, which defy the power of most implements either to pierce or reduce them. The first ploughing in breaking up from grass or stubble requires the strength of four horses, and this at any time of the year, except in the earthing-up furrows for seed in October: at that time two horses with a swing plough are sufficient, as the very adhesive soil has crumbled into mould from the effects of the autumnal rains after the summer's baking in the sun. All light ploughs, whether swing or provided with wheels, are wholly inadequate to the purpose of ploughing these lands: the weight is insufficient to pierce the soil; the strength is unequal to the resistances that are offered; the wing of the share cannot force a way among the viscous ingredients, the waxy soil adheres to the metal mould-board, and being pushed before the concave breast of that implement, falls off in lumps. The well-known turn-wrest plough has been very properly devised to suit the peculiarities of the soil; the weight and strength of the implement are able to overcome the resistances that are offered; the length of the body ensures a steady motion; the rounded and narrow-pointed share finds or forces a passage through the tough and waxy soil, while the wooden mould-board throws off the furrows, as the soil does not adhere to wood as to the cast-iron plate of the common ploughs. The draught chain of the turn-wrest plough is bent upwards to the middle of the beam, by which curvature a part of the drawing power is exerted in pulling and keeping the plough in the ground, which forms the most essential point of the operation in ploughing the plastic clays. This very strong and heavy implement is required during the whole process of summer fallowing, and the power of four horses is absolutely necessary. The roll or harrows of any weight produce little or no effect on the hardened masses of plastic clay till the change of the season into shorter days and longer nights introduces a cooler influence, and the autumnal rains assist in mouldering the baked lumps of the aluminous earth. At that time the harrows are employed in tearing asunder the pieces of soil, which are very wonderfully softened during the season of autumn. A very minute reduction of the soil is never done or attempted, and is not wished, as a cloddy surface holds and shelters the plants of wheat during winter much more beneficially than a pulverized mouldy top of soil. The clods are dissolved during winter and cover the wheat plants, and in the spring afford a fine earth to be harrowed with the grass seeds, and act as a top dressing. The last ploughing of the plastic clay land, the ridging-up furrow, or the seed furrow, is done by two horses with a swing plough, and best with a wooden mould-board, to which the soil does not so much adhere as to metal. In wet seasons, when the land becomes heavy, three or four horses are required even in the swing plough in the last operation of the seed furrow. The proximity of the plastic deposit to the chalk formation has in several places introduced a large mixture of flints into the waxy mass of clay, which, being firmly imbedded in the stubborn soil, render the ploughing more difficult, and increase the necessity of having a narrow-pointed share without a wing, in order to penetrate the very firmly cemented mass of soil. The mould-board is also required to be placed high from the ground, as in the turn-wrest plough, so that it does not come into contact with the furrow till it is raised by the boring of the share; the low position of the metal mould-board of the common plough encounters an overwhelming opposition to its progress, even if the winged share did succeed in piercing the soil and raising a furrow, which it never can accomplish. Not only is the turn-wrest plough absolutely necessary to cultivate the plastic clays, but a heavy kind of the same implement is required for the most obdurate clays, while a lighter plough of the same kind is used on lands of a milder formation of the plastic clays, and where the flints are less abundant, and not so firmly imbedded in the waxy texture of the land.

Four earths, including the winter furrow, are generally sufficient for summer fallowing the plastic clay lands, and the seed furrow before mentioned covers the dung, when the seed is immediately sown by hand, or by drill,—sowing early on these precarious lands. Or the farm-yard dung may be applied in the early autumn, on the last complete ploughing and harrowing of the land, or the ridges gathered up by a swing plough, when the seed furrow in October will form the fifth earth or movement of the land by cultivation. This is the general and most approved process. The tough waxy texture and repulsive nature of the soil prevents the action of any manure except that of farm-yard dung in a half-rotted state, which should be used in the quantity of twelve to twenty cart-loads of two horses' draught. In the spring months, top-dressings of soot, sugar scum, nitrate of soda, or any pulverulent bodies which last only for one year, are very useful to the wheat crop, and also on the succeeding clover crops; but no light or auxiliary manures receive admission into any incorporation with the stubborn soil itself. The solid matters of farm-yard dung remain in the ground and are dissolved gradually, and add to the bulk of the earthy staple, which is naturally very small or none.

The rotations of cropping that can be used on the plastic clays are few, and of the most simple description. Root crops of any kind are wholly and entirely beyond the question; the leguminous plants are not much to be commended, though they may be sown, and the returns are not to be refused. The cultivation reverts to a dead fallow, as the basis of any use of the land, to be followed by wheat, as the most profitable of the grain crops. Barley is wholly forbidden; and oats do not thrive much upon the waxy clay. The course of cropping has been used thus :—

1st year . .	Summer fallow (dunged and limed).	2nd year	Wheat.
		3rd „	Clover.
		4th „	Oats.

This rotation is too short for any lands that are remote from the sources of extraneous manure: but there is a great difficulty in extending it upon the plastic clays. Peas are completely set aside as a crop, and, the land not allowing any spring preparation for beans, that plant must be sown in broad-cast, and then it is no better than a culmiferous crop. In the early growth the crop of beans may be hand-hoed in broad-cast, and the weeds checked; but the benefit obtained is very trivial. Even the next alternative in sowing beans is derived by severely and deeply harrowing the winter ploughed surface, and then ribbing it into ruts by one-horse ploughs, in which the beans are sown by hand, or in drilling them by the machines for that purpose. In these ways the work is done across the winter ploughing. Except on the drier modifications of the plastic clays, these operations cannot be done. On the most obdurate plastic clays, and more especially where the flints are abundantly mixed with the soil, any preparation of the land is impossible, except by the operation of summer fallowing for the crop of wheat, and the beans must be cultivated in broad-cast, and hand-hoed in the early growth. The bean crop may appear in two ways :—

1st year . .	Fallow, dung and lime in 200 bushels an acre.	2nd year	Wheat.
		3rd „	Clover.
		4th „	Beans.
		5th „	Oats.

Or—

1st year	Fallow.	4th year . .	Oats or wheat.
2nd „	Wheat.	5th „ . . .	Clover.
3rd „	Beans.	6th „ . .	Oats.

On the most favourable qualities of plastic clay lands a crop of winter or spring tares is admitted, and much benefit is derived from its use. Being consumed on the ground by sheep, it prepares the land for a crop of wheat—the winter crop, by its early consumption, allowing a partial fallowing of the land, and the summer crop giving time for one ploughing of the land in October for the seed furrow. Then the course of cropping will be altered thus:

1st year . .	Fallow, dung and lime.	4th year . .	Oats or wheat.
2nd „ . . .	Wheat.	5th „ . .	Clover.
3rd „ . . .	Tares.	6th „ . .	Beans.
		7th „ . .	Oats or wheat.

And—

1st year	Fallow.	4th year	Oats.
2nd „	Wheat.	5th „	Beans.
3rd „	Clover.	6th „	Wheat.

The course of five years may be well used on any description of the plastic clays, having two years in grass, where the land is duly prepared, and the proper grass seeds are sown. The land being frequently drained will not in any way damage the sheep by the wetness causing the rot. The rotation will be—

1st year . . .	Fallow, dung and lime in 200 bushels per acre.	2nd year	Wheat.
		3rd „	Hay.
		4th „	Pasture.
		5th „	Oats.

And may be extended,—

6th year	Beans.	7th year	Wheat.

This course very much benefits the land, by producing the vegetable sward for the growth of the oats, and is well ascertained to be superior to any manure that is yet known. The grasses sown may be :—

	Per Acre.		Per Acre.
Red clover . . .	6 lbs.	Dogstail	4 lbs.
White clover . .	2 „	Meadow fescue . .	4 „
Cocksfoot . . .	$\frac{1}{4}$ bushel.	Catstail	4 „
Ray grass . . .	$\frac{1}{2}$ „		

The very clammy and adhesive texture of plastic clays requires the thorough draining to be very closely done, and in distances of four or five yards between the drains. And after a varied experience of draining clay lands, we do not hesitate to state our candid opinion, that a wider distance will not make the lands dry, and the depth of $2\frac{1}{2}$ ft. is amply sufficient, with a foot of earth laid over the stones or tiles which form the cavity of the drains. We also recommend that the drains be run longitudinally in the furrows, and the ridges being yearly and permanently gathered up by the plough, a convexity in the form of the land is produced, which throws the water to the furrow, whence it passes into the drain through a thin stratum of soil left by the plough, of a thickness not to allow the disturbance of the materials of the drain. There is no better mode yet known of draining very wet clay lands.

The plastic clays that lie north of the Thames are very much modified, and reduced from the viscous tenacity which is found in the pure qualities of the marine deposit on the southern slope of the northern chalk downs which form the south boundary of the London basin. In these situations the flints are very thickly imbedded, and the soil is seen in a dry red clay near to the top of the chalk hills, and in a most waxy black stratum towards the lower parts of the declivities. Both conditions form a soil for cultivation that is most perplexing and of little value ; but being generally joined with other soils in the very varied stratifications of these localities, the single worth is seldom estimated; it cannot exceed 12*s*. or 14*s*. per acre. The land is best adapted for grass, but much manure is required, in ample doses and in very frequent repetitions, to destroy the mosses and preserve the useful grasses. The situations of the plastic clays do not favour this use of the land, as being without the reach of an extraneous supply of the dung of animals and vegetables, which alone can impart any lasting benefit to the waxy texture of the plastic composition.

The next marine deposit, and which directly overlies the plastic formation, is the

London Clay,

which occupies the valley of the Thames, commonly called the London basin, extending from the mouth of the river to above Hungerford in Berkshire. It lies deep in the London concavity over the chalk, the borings varying from 400 to 700 ft. This great argillaceous formation is rendered highly interesting by the variety of its organic remains, both animal and vegetable, and by the inferences deducible from them. The number of species which can be completely identified with recent analogies is small, and points to its comparatively remote antiquity; and its vertical position in the Isle of Wight evinces that convulsions took place previously to the deposition of the upper horizontal beds, and that a sufficient interval had elapsed to give a very considerable degree of consistency to the clay before these newer strata were accumulated upon it. The name is derived from its forming the general substratum of London and its vicinity, occurring immediately beneath the vegetable soil, except when occasional deposits of alluvial or diluvial gravel, sand, and freshwater soils intervene.

This formation consists chiefly, and sometimes wholly, of bluish or blackish clay, which is very tough. The variations of the chemical and external characters, either partial or local, are inconsiderable. Some of the strata are marly, and effervesce with an acid, sometimes strongly. In the Isle of Wight it contains much green earth. Occasionally it includes beds of sandstone. Limestones and siliceous rocks are found imbedded in the cliffs of this clay, and inclose the same fossils. The cliffs near Harwich, in Essex, contain beds of stratified limestone. The lead gray or blue colour changes into dull brown and red, perhaps most usually in the lower part. Green grains and sandy layers occur, which last are often indurated into a considerable rock. Septaria abound in it, or ironstone minerals of a round compressed form, and internally divided by septa or thin partitions of lime, spar, or pyrites, and some imperfect laminæ of marly limestone have been noticed. Sulphuret and phosphate of iron and selenite are interspersed through the London clay, and hence the water of the aluminous stratum is unfit for domestic purposes. It is also suspected to contain some sulphate of magnesia. Amber and fossil resin are found in the gravel about London and Highgate, and at Holderness, in the south of Yorkshire.

The number, beauty, and variety of its organic remains render the London clay very interesting, and there are rich repositories of these relics in the cliffs at Harwich, Sheppey Isle, Hordwell, Stubbington, and other places. Shells of the most delicate and fragile form are perfectly uninjured in this clay, except in the rare case of its being laminated. The crocodile and turtle are found in the London clay, among the amphibious class of the higher order of animals, of which the eggs may have been deposited on some dry land that was accessible to the presence of water. Several beautiful species occur of vertebral fish, and the crustaceous division shows the lobster and crab. There are very few genera of recent shells which have not some representative imbedded in this formation, but the specific character is usually different; on the other hand, but few of the extinct genera, so common in the older formations, occur in this, so that it seems to hold a middle character in this respect between the earlier and more recent beds. Shells of the chalk are very rare in this formation, as also in the contemporaneous strata of France. Zoophytes are also extremely rare. Testaceous fossils are uncommonly numerous. Clays and argillites harden by contraction, and shells found in clays are mostly compressed and flattened; but those found in limestone retain the primitive shape, as that rock hardens chiefly by infiltration.

It frequently contains small portions and even masses of wood, more or less retaining the woody fibre, but more often having the appearance of being charred, and of a black colour. They sometimes exhibit the perforations, and even contain the casts, of an animal which is considered to be analogous to the "borer," which still infests the seas of the West India Islands. The wood is often surrounded by masses of argillaceous limestone, mostly in the form of septaria, which are characteristic of the London clay; they often contain shells still exhibiting the pearly lustre. The vegetable remains are uncommonly numerous, and the fossils are abundantly found wherever the sea has laid open natural sections, or artificial excavations have been carried on to any great extent.

Wherever this clay is visible in the form of a cliff, or has been perforated in sinking wells, it has uniformly been found to contain nearly horizontal layers of ovate or flattish masses of argillaceous limestone, which are mostly traversed, or have been traversed, by cracks wholly or partially filled by calcareous spar or sulphate of barytes, which have obtained the name of "Septaria." These masses abound so greatly that they have been considered as being characteristic of the London clay; but it is not the only one of the English beds which contains them.

This formation is uniformly marked as consisting of a vast argillaceous deposit, containing subordinate beds of calcareous concretions, sometimes passing into solid rocks, or exhibiting some local variations, from the occasional mixture of sand or calcareous matter in the mass of the clay. These local changes, however, never prevail to such a degree as to interfere materially with the general identity of character. The London clay possesses all the appearances of a very quiet and continuous deposit, perhaps in deep water, yet not far from shore, since a few considerable remains of land and littoral productions occur in it, as wood, turtles, and crocodiles, but no pebbles nor coarse sands. The temporary turbulence of the plastic clay period had wholly passed away, and only finer sediment in great quantities found its way to the sea. Having been much exposed to watery action, which it could ill resist, it is often left in insulated hills, upon the substrata of sand and clays. Mineral springs, so common to blue clays, rise in considerable number near the metropolis. The most remarkable are those of Epsom, famous for their sulphate of magnesia, Bagnigge Wells, and Acton. The dense nature of the clay stratum throws upwards in pumps the water of the alluvium, which is limpid and comparatively soft for common use. The water of the London clay is impure and hard, from containing salts, and from the decomposition of the pyrites, which abounds in the formation. The water drawn from the deeper lying plastic clay is very limpid and free from salts, and large streams of water rush up, when, as circumstances may require, the perforations are extended to the chalk, which underlies the whole basin of London, from the chalk of Surrey on one side, to that of Hertfordshire on the other.

The range and extent of the London clay as a surface soil is very considerably larger than that of the last-mentioned deposit, or the plastic formation. It occupies the entire concavity of the area of the chalk, from the hills of Croydon, on the south, to the northern boundary of the chalk range of Hertfordshire, supporting the metropolis, the upper marine formation of the sands of Hornsey, Highgate, and Hampstead, and the alluvial deposit of gravels, sands, and loams on both sides of the Thames. The county of Middlesex is chiefly occupied by the London clay, and nearly the whole of the county of Essex. In Suffolk it extends from Orford to Harwich, and to the north of Ipswich, and hence to Roydon, in Essex. It occupies the south-eastern corner of Hertfordshire, at Cheshunt, and also the south-western part by North Mimms, Ridgehall, Aldenham, and Bushey, to Hatfield, in Middlesex. Berkshire contains much London clay in the valleys over the chalk, and in the bed of the Thames from Reading down the course of the river, and only a small portion of London clay is found in Buckinghamshire, in the neighbourhood of Staines. In Kent, the clay appears on the northern side of the Medway, constitutes the Isle of Sheppey, lies from Whitstable to Canterbury, and thence to Boughton Hill. A small patch of it is visible on the south-west of Ramsgate, in Pegwell Bay. Shooter's Hill, near Woolwich, is an insulated mass of London clay, and rises to the height of 446 ft. The hills of Sheppey are 200 ft. high. In Surrey, the low part of the county, from near Croydon to the Thames, and from the Kentish border to Hampshire, is occupied by the London clay, covered in many places by the fresh-water alluvium. Some valleys contain London clay between the north chalk range and the iron-sand rocks of the Wealden formation. The London clay constitutes the flat maritime district of the south-west part of the county of Sussex, and in some localities includes beds of gray limestone and sandstone, and the limestone composes groups of rocks on the coast. The London clay and the Bagshot sand are found only in the north-east of Hampshire, and are much exceeded by the plastic clay. A part of the New Forest is occupied by it, with the country round Southampton Water, and the whole line of the coast eastward from the Avon, and including Portsea and Hayling Islands. The few clays of Wiltshire are ascribed to the plastic formation and Tetsworth bed. In the chalk basin of the Isle of Wight the London clay is very extensive, forming the whole coast from Worthing, in Sussex, to Christchurch, in Hampshire, and extending from the latter place inland by Ringwood, Romsey, Fareham, and passing south of Chichester to Worthing. It forms the whole of the tract from the above-named places to the coast, except where it is covered by alluvium, or by a sandy tract, analogous to the Bagshot sands, constituting Beaulieu Forest and a part of the New Forest. In the Isle of Wight it extends, in a vertical position, along the island, from Alum Bay on the west to Whitecliff Bay on the east, between the nearly horizontal fresh-water and upper marine beds on the north, and the nearly vertical beds of the plastic-clay formation on the south of it. Bognor rocks consist of it, and the clay forms the bottom of the channel termed the Solent, which is between the Isle of Wight and the coast of Hampshire.

The sinking of wells and the cutting of roads has sufficiently proved the occupation of the above-mentioned tracts by the London clay, as has been described in treating of the chemical and external characters of this stratum, and the numerous and extensive cliffs which it forms have been mentioned as being particularly favourable to the collection of the organic remains which it incloses.

The country formed by this stratum of clay is generally low, and may for the most part be considered as flat, or, at the most, as consisting of very gentle undulations. Here and there, however, it rises. The highest point of 759 ft. above the level of the sea is in Essex; Shooter's Hill, in Kent, is 446 ft.; and Richmond Hill and St. Ann's Hill, in Surrey, are less elevated. There are cliffs of London clay in the Isle of Sheppey, 90 ft. high, which extend four miles in length, and decline gradually towards the east and west. These cliffs have been formed by the action of the sea, and whole acres of them sometimes fall at once. The Isle of Thanet shows cliffs 70 ft. in height, and Hordwell Cliff, in Hampshire, is 150 ft. high.

The beds of this clay are so nearly horizontal that no perceptible difference from that position has been observed in the chalk basins of London and the Isle of Wight, except in the isle itself, where this bed is nearly vertical. This extraordinary deviation in regard to position is always treated along with the numerous accompanying beds of sand and clay belonging to the underlying plastic formation, and of the chalk, of which the position is nearly the same. The central chalk ridge is highly inclined, and the plastic and London clay are to the north of it, and are respectively 1131 ft. and 250 ft. thick. On the north and south the more recent formations are horizontal, or nearly so, being deposited unconformably on the broken edges of the vertical strata. The disturbing force that occasioned the vertical position acted along a line that can be traced as far as Abbotsbury, in Dorsetshire, 60 miles east and west from the eastern end of the island. A highly inclined saddle of the substrata may be traced in the continuation of the same line. The geology of Britain does not present any more extraordinary appearance than the nearly vertical position of the chalk, and the two overlying clays, placed in a narrow confinement between the adjacent undisturbed strata. The vertical position is much concealed by grassy slopes; but the cliffs, being constantly worn down by the action of the sea, expose the high inclination to the view of wonder and admiration.

The London clay presents a surface soil for cultivation that is less waxy and slippery than the plastic deposit, but fully as obdurate and intractable in the management. The wet condition of it is not slippery, but the soil adheres to the feet. In dry weather the firm land opens into chinks that are both wide and deep, and endanger the traversing of the ground on horseback. In an arable condition the soil, when the least damp, is pushed before the breast of the plough, and falls from it in large lumps, and in dry weather the hardened masses of soil most obdurately resist the action of any implements of mechanical power. The ploughing of the land requires the power of four horses with the strong turn-wrest plough that was mentioned in last chapter, and that during the whole summer, till the seed furrow in October is done by the swing plough of two horses in ridging up the ground into the proper form. In the dry months of summer the harrows and roll are not able to produce any impression on the hardened clods of the fallowed ground, till the approach of autumn introduces a cooling influence and a crumbling effect, when the land falls into a black mould, which is produced by the relaxation of the baked condition of the soil by the heat of the sun. On this pulverized soil at the end of August, or early in September, the lime (if any) and the farm-yard dung are spread, and ploughed under by the swing plough. The ridges are formed by the land being gathered up, and another similar process in October receives the seed, which is covered by harrowing, and the furrows are opened.

The modifications of the London clay are more numerous than those of the plastic fornation, and the course of crops on the land admits more variation. The texture is somewhat softer, and the general quality is better; still the management does not differ very much, but may be something more extended, and will prove more useful. The general course, as given below, is too short :—

1st year . .	Fallow, dung and lime in 200 bushels an acre.	2nd year	Wheat.
		3rd "	Clover.
		4th "	Oats.

Extended—

5th year	Beans.	6th year	Wheat.

The beans are drilled across the land on the deeply harrowed surface of the winter ploughing, and the wheat is sown on the bean gratten with one furrow of the land. No soil of the London clay permits any movement of the land in the spring for preparing the ground for beans, and the next alternative is used of sowing the crop on the harrowed surface. Even this preparation is not allowed by the larger part of the London clay soils, and the crop is sown broad-cast, when it ranks as a grain crop. But in some places this harrowing can be done.

Peas are not introduced in cropping the London clay lands, but tares are to a considerable extent very useful. The winter variety affords an early food, and continued through the summer, when the land, after being manured by the excrements of the sheep, and the weeds being killed by the smothering herbage of the vetch, will be found in a mellowed condition for receiving the seeds of wheat, for which one ploughing is necessary. The spring vetch may be used in a similar manner, and a partial fallowing is often given to the land, after the herbage is consumed; but the former mode may be preferable.

The rotations are as under:—

1st year . .	Fallow, dung and lime.	Or—1st year .	Fallow, dung and lime.
2nd „ . .	Wheat.	2nd „ .	Wheat.
3rd „ . .	Clover.	3rd „ .	Beans.
4th „ . .	Oats.	4th „ .	Wheat.
5th „ . .	Tares.	5th „ .	Tares.
6th „ . .	Wheat.	6th „ .	Wheat.

This course may show too many crops of wheat, and oats may be substituted, thus :—

1st year . .	Fallow, dung and lime.	4th year	Beans.
		5th „	Wheat.
2nd „ . .	Wheat.	6th „	Tares.
3rd „ . .	Clover.	7th „	Oats.

The course of five years, with two years in grass, can be very advantageously used on the clays of the present description, thus :—

1st year . .	Fallow, dung and lime.	3rd year	Clover.
		4th „	Pasture.
2nd „ . .	Wheat.	5th „	Oats.

Extended—

6th year . .	Beans or tares.	7th year	Wheat.

The grasses to be sown for pasture are, per acre, as under :—

Ray grass . . .	½ bushel.	Dogstail	4 lbs.
Cocksfoot . . .	¼ „	Red clover . . .	6 „
Catstail	4 lbs.	White clover . .	4 „
Meadow fescue .	4 „		

The seeds of the grasses, well mixed, are sown by the broadcast box machine, and the surface is well pulverized for wheat by harrowings before the seeds are sown, and also after that operation, in order to cover the seeds, when a heavy rolling finishes the process.

Farm-yard dung is the only manure that can be used on the clay lands now mentioned, except the usual substances for top-dressings on the grains and clovers of the spring. The adhesive soil does not admit the action of any fine substance, nor any reciprocal affinity of mixed ingredients. The draining of these lands must be such that the distance between the drains shall not exceed five yards, and they are best placed in the furrows, as before mentioned. The ridges being kept in one form, and being gathered into a rounded convexity by the ploughings, the water is thrown to the furrows, where it passes into the drains with very little hindrance. The depth of 2½ ft. will allow 21 in. of cavity, and 9 in. for the furrow, and which, being about 6 in., leaves 3 in. of percolating stratum, which is quite enough to protect the drain from being disturbed ; for, in all purely clay soils, the drains cannot be too near the surface, provided they are not disturbed. The dryness of the land depends on the ready access of the water to the drains from a distance and from the tops.

Both the London and the plastic formations of clay are much best used in grass; but the contiguity of a plentiful supply of rough manure for top-dressings, such as London or similar large towns can afford, is understood. The applications must be very liberal and frequently used. By these means the fields of grass round the metropolis have been converted into a rich hotbed of production; an earthy stratum has been formed in which the ootsr of the grasses are fixed, that has little connection with the clay below, and which has been produced by the decay of the earthy matters of the dung, and the roots of the herbage. Even in inland situations a large use may be made of this clay ground in permanent grass, especially where land of some other more easily arable formation is joined with it in the same form. This arrangement should be much studied in the pitching of farms, and the clays being always interpolated among other deposits, the extent of ground is not required to be large in order to include a variety of soils, which, inducing a mixed cultivation, very much increases the relative value of the different descriptions of land. A farm is truly a heartless concern that is wholly composed of such clays as the plastic and London deposits; but being mixed with loams, sands, or chalks, as they generally are, the cultivation is not so irksome, or the occupation so very disagreeable. The London clay is most generally accompanied with the plastic formation, and both depend upon the chalk, and also upon peculiar deposits of that stratification, and are chiefly confined to the basin of London. A small part is lodged in the basin of the Isle of Wight, and the quantity beyond the north boundary of the London concavity is inconsiderable. It extends from Reading, in Berkshire, down the valley of the Thames to the mouth of the river. Both formations are much alike, differing not much in the materials, but in the quantity and variety of the ingredients, and something in the time and extent of the deposition by agencies of a turbulent as well as quiet operation. The London clay is poor in quality as cultivated land, and it requires much manuring to raise upon it any crops of the ordinary amount and quality. The individual value would not exceed 12*s.* to 16*s.* per acre, and the first-rate qualities of the ground will be required to reach even that amount. The inferior soils of that denomination scarcely rise beyond the cost of seed and labour.

The quantity of lime that is used on the plastic and London clays must be very liberal, and the surface of the land must be very finely pulverized, that the powdered lime may be intimately mixed with the earthy alluvium. Clay is a very bad conductor of heat, and a large quantity of lime, or the element of caloric, is required to impart warmth to its aluminous mass. The quantity of 200 bushels is a medium allowance, and must be repeated in at least every third return of the fallowing of the land. Distant applications of lime lose all effect between the long intervals.

The Argillaceous Golt,

Gault, or Gebirgsart of the Germans, imports, in the strict meaning, an earth of the hills or mountains, as it lies between the layers of the upper sandstone which is covered by the chalk. It is therefore a marine formation, being included in the secondary strata, which everywhere exhibit the most evident marks of an aqueous agency in their deposition. It is the argillaceous member of the green-sand group, which is very intimately connected with the cretaceous system, and the two beds comprehend all the layers from the lower or iron sand to the upper chalk, which is included. The complete system here contained is found in many parts of England; but not unfrequently deficiencies occur, the upper sand being largely developed or often wanting; the intervening gault and the lower sand being much contracted, while the latter body often almost wholly disappears. The proper position of the gault is the dividing stratum between the upper and lower green sands, that are commonly called the green and iron sands. The average thickness is about 100 ft., and no remarkable peculiarity of mineralogical aspect or chemical composition distinguishes the gault, except a general tendency to admit green grains into its more sandy portions. It yields a most rich supply of molluscous remains, many of them minute and of the greatest beauty, and presents a varied treat to the conchologist. Small irregular iron-stone nodules are found in it, and the varied abundance of organic remains serves admirably to complete the catalogues of fossils of the cretaceous system. The colour of the gault clay is dark blue, and often light gray.

The gault must be considered as the "shale," or the clayey accompaniment of the upper deposit of sandstone, which is immediately covered by the chalk. Consequently it deserves a place among the clays from the shale; but the quality of the soil for cultivation being so very similar to the plastic and London formations, and the geographical position being much intermixed with these clays, it has been preferred to describe it in this place. The organic fossils of the gault point to an epoch anterior to the present zoological period; and being placed below the chalk, the kinds of life are now extinct that are imbedded in the special argillaceous deposit. It forms universally a characteristic narrow valley under the cretaceous formation, and as it lies below the huge deposit of chalk and the upper sandstone, a very deep-working denudation must have caused the exposure of the gault in the comparatively few places where it occurs. This vast power may have carried the chalk from the whole Wealden formation of Kent, Surrey, and Sussex, and laid bare the gault and iron sands; the valleys being afterwards filled with the fresh-water clay of the Weald, as will be afterwards described.

The gault clay is seen near Godstone in Surrey, in the south valley at the foot of the North Downs, and is called "black land." It is largely accompanied by the sands of the same deposit. In Sussex and in Kent it is seen in several places covering the iron sands, and cropping out from below the green sand. In the isles of Wight and Purbeck it separates the iron and green sands, and follows with the same relations the range of the green iron sand in the surrounding chalky districts. In Buckinghamshire it forms the Tetsworth clay above the chalk marl, and the ferruginous sandstone is interstratified between them. All these formations are much covered and concealed by the débris of the chalk hills, which, being mixed with the clay, or the so-called gault, forms the rich vale of Aylesbury. In Berkshire the appearances of gault are very small, and, when in conjunction with the sands, the mixtures almost destroy the character. In Bedfordshire the blue gault is much mixed with the chalk marl, the former being reckoned identical with the Folkstone clay. In Cambridgeshire the chalk rests upon a blue clay, called in the county "gault," which is considered as a variety of the chalk marl formation that crops out from beneath the north-western boundary of the chalk. The surface extent is large, and the thickness variable from 200 to 220 ft. In Wiltshire the gault or Tetsworth clay occupies a narrow tract surrounding the superior formations, and runs by Swindon and Devizes into Somersetshire. In some places it is covered by the green sand, and in the vale of Wardour it is seen to skirt the upper sand. In Yorkshire, the Speeton clay underlies the chalk, but does not graduate into it. The organic remains are numerous, different from those in the chalk, and also different from those in the strata below. They appear to have analogies to the gault of the south of England, and also to the Kimmeridge clay; but the former prevail. This clay is mentioned as being the gault, but the necessary sand deposits are wanting.

The gault appears in its pure condition in Surrey, where the denudation has been complete by the removal of the superincumbent sandstone and chalk. The next best specimen is the Tetsworth clay of Oxford and Buckinghamshire, which has not been so much denuded, but is largely intermixed with the waste of the chalk hills, which has very much modified its character. In Huntingdon and Cambridge, the large quantity of chalk marl wholly alters the formation of the underlying clay which overlies the iron sand. The diluvial débris of the neighbouring chalk covers deeply all the surrounding contiguities of formation. The gault is very much or almost wholly altered by the absence of the upper sand, and by being graduated into by the superincumbent chalk, which passes into a marl, and commingles with the argillaceous deposit.

The cultivable character of the gault of Surrey is very similar to the London clay; the stubbornness is not quite so obdurate, and the viscous quality is less abundant. But its general property compels a course of cultivation that is applicable to the very stiffest clays. Green crops are wholly inadmissible, and no preparation can be given to the land in the spring for a crop of beans. The bare fallowing of the land for wheat is necessarily adopted, and the beans are sown in broad-cast, as on the stiffest plastic clays. It is difficult to advance improvements on lands of this description. Where no auxiliary cultivation can be added to the process of summer fallowing, the course of cropping must be short, in order to have the process repeated, as no amelioration can be effected between the operations. Consequently the crops are all of the scourging nature, and the land being naturally poor in quality, the two tendencies, one natural and the other adventitious, concur in rendering the cultivation both heartless and profitless to the husbandman. A crop of beans is generally understood as a half-cleansing crop, and when circumstances deny that property, the use of the plant becomes little eligible, if not wholly objectionable. The excretory roots of the bean may confer some little benefit on the soil; but as no cultivation is given to the land, either in the spring or during the summer, and no manure is applied, the crop is no better than a grain crop, and the surface is always more encumbered with weeds after an imperfect crop of legumes, than when a culmiferous crop has succeeded. The four years' course is stated again :—

1st year	Fallow, dung and lime in 200 bushels an acre.	2nd year	Wheat.
		3rd "	Clover.
		4th "	Oats.

The shortness of this course is an objection to its use, but for the reason before given, that no intermediate assistance can be given to the land between the fallowing, the repetition of that process becomes the more necessary to put the land into the best condition for being cropped. Wheat is the most valuable crop that can be got, even in the small quantity that is grown on the gault clays; oats thrive very poorly on waxy clays for want of the loamy adhesiveness, and clover labours under the same predicament. It is not eligible, in fact it is very objectionable, to have two crops of the same plant in one course of rotation; yet, when beans are introduced, there seems a necessity for the admission. Thus :—

1st year	Fallow, dung and lime.	3rd year	Clover.
2nd „	Wheat..	4th „	Beans.
		5th „	Wheat.

Oats may be sown in the fifth year; but experience shows that wheat is in all cases the most profitable grain for adoption. A longer course would stand thus:—

1st year	Fallow, dung and lime.	4th year	Oats.
2nd „	Wheat.	5th „	Beans.
3rd „	Clover.	6th „	Wheat.

This rotation is much the best adjusted, if the bean crop could be so fashioned as to impart some benefit to the land by manuring and working, in order to sustain the following crop of wheat; but the most stubborn gault clays do not allow any preparation, not even deep harrowing of the ploughed surface on which to drill the beans; the crop is therefore in broad-cast, and during the early growth the weeds are checked by hand-hoeing; consequently, the cropping of the land for six years till the fallowing returns is too severe a process of usage, and is scarcely admissible in the clays now described. Tares thrive very poorly on the gault, but the crop may be tried in the way stated for the London clay.

The course of cropping on the gault, as on the plastic and London clays, is much more advantageously prolonged by having grass for two, if not for three years, and depastured by sheep and cattle. The land is rested and acquires a grassy surface, on which, in the decomposition, the oats are nourished. A crop of oats is wholly owing to this vegetable decomposition, and the freshness which the soil obtains constitutes the pabulum of future crops. The rotation would be—

1st year	Fallow, dung and lime.	3rd year	Clover.
2nd „	Wheat.	4th „	Pasture.
		5th „	Oats.

Or—

5th year	Pasture.	6th year	Oats.

The grasses to be sown, per acre, are—

Ray grass	½ bushel.	Dogstail	4 lbs.
Cocksfoot	¼ „	Red clover	6 „
Meadow fescue	4 lbs.	White clover	4 „
Catstail	4 „		

Our own experience in the management of clay lands has been very long, and extensively varied, and most fully justifies the recommendation of the course of cropping last stated, as the most useful and beneficial on all lands that are not adapted for green crops. The land being thoroughly drained, and the herbage being young and fresh, no tendency to rot is imparted to the sheep that graze the surface, and the pasture is more valuable than any one of the scanty crops that are obtained by constant cropping. The course may be lengthened into eight years, thus:—

1st year . .	Fallow, dung and lime in 200 bushels an acre.	4th year	Pasture.
2nd " . .	Wheat.	5th "	Pasture.
3rd " . .	Clover.	6th "	Oats.
		7th "	Beans.
		8th "	Wheat.

This course includes the use of pasturage and beans, which prepares the land for oats and wheat in the most superior manner.

The true gault clay requires the strong turn-wrest plough of Kent for the purposes of cultivation, and the entire management differs nothing from the London clay, which in many places it closely adjoins in its geographical position. The viscous adhesion is not much less, and it clings during wet weather to the feet and to the metal of ploughs, so as to require the timber board of the heavy plough. Harrowing and rolling are not much required during the summer fallowing, as the land falls during autumn into a very fine and soft powder on the surface, in which the wheat plants have a slender hold, and are often thrown out before the second growth of the spring obtains its firm consistency; consequently it is preferable to have the surface in a cloddy condition of roughness, between which the roots of the wheat plants get a hold of the firm ground underneath, and the falling into pieces of the clods during the winter and spring covers the plants and protects the roots. Farm-yard dung is the only manure that can be used, and is applied on the fallows for wheat. The usual top-dressings are used on the young crops of the spring. The draining of the gault clays must be frequent, the drains being five yards apart, and placed and filled as before mentioned. The value of gault land by itself will not exceed 12*s.* per acre.

The modified gault in the Tetsworth clay presents a soil that is very considerably relaxed in the viscous adhesion, and in which the obdurate tendency is very much diminished. The commingling has been very large with the chalky detritions, and the character partakes of the mixtures with the argillaceous deposit. The aluminous quality is still obstinate, and the land must be cultivated by the summer fallowing process, which can in no case be omitted. But the land can be ploughed with a strong swing plough drawn by four horses in the winter furrow, and by two horses during the summer operations. The usual harrowings and rollings can be used in the cultivation of this clay land, but at some seasons it gets into very peculiar condition, and baffles management. As in all clay lands, all operations must be done in dry weather, as a very small degree of wetness glazes the soil and cements the particles. The texture of the soil hardly allows any preparation in the spring for beans, and deep harrowing becomes necessary, on which the seeds can be sown by drill machine, or in ruts that are made by small ploughs, and both modes are done across the winter furrows. If no manure is applied, the movement of the soil by the hoeings is very beneficial to the land. The rotation will be—

1st year . .	Fallow, dung and lime in 150 bushels an acre.	3rd year	Clover.
		4th „	Oats.
		5th „	Beans.
		6th „	Wheat.
2nd „ . . .	Wheat.		

And with pasture—

1st year . .	Fallow, dung and lime.	4th year	Pasture.
2nd „ . .	Wheat.	5th „	Beans.
3rd „ . .	Clover.	6th „	Oats.

Or—

5th year	Pasture.	6th year	Oats.

The grasses to be sown are, per acre,—

Ray grass . . .	$\frac{1}{2}$ bushel.	Dogstail	2 lbs.
Cocksfoot . . .	$\frac{1}{4}$ „	Red clover . . .	6 „
Meadow fescue .	4 lbs.	White clover . .	2 „
Catstail	2 „		

In every case of sowing grass seeds, the surface of the ground must be minutely pulverized by harrowings before the seeds are sown, and the operation repeated after sowing. The heavy roll finishes the process.

Farm-yard dung is the only manure which the Tetsworth clay will receive, except in top-dressing the spring crops on the young braird. The draining may be done in the distance of five or six yards from drain to drain, and filled as before described. The value of the land is about 16*s.* per acre, producing three to four quarters of wheat. The quality of the land is inferior to the best kinds, and superior to the worst varieties of the plastic London and gault formations.

The so-called gault of Huntingdon and Cambridge is still farther removed from the true type than the clay of Tetsworth. The land is still tough in the texture, partially viscous, and requires the process of summer fallowing to prepare the ground, as green crops are denied. But the swing ploughs are sufficient, with four horses in the winter furrow, and two during summer. Draining is not universally required, as the clay is much dried by the mixture of chalk. The mode of draining, the systems of cropping, manures, and grass seeds, are the same as for the Tetsworth clay. The quality of the land is superior, and fetches a higher value, being much mixed with turnip soils of the chalk and loams.

The gault clay is confined to the chalk districts, and to the south-eastern portion of that range of formation. Except in Surrey, the true type is not found; the clay is often almost wholly lost in the upper sand, and when the sand is absent, the chalk descends into the gault, and much alters its constitutional character. The name is preserved and applied to the clays that are seen associated with the sands below the chalk, though the true deposit is seldom exposed, and consequently not much known. The gault is seen in the perfection of a cliff of 120 ft. thick at Folkstone, resting distinctly on the lower green sand, the section being well exposed, and the stratum exceedingly fossiliferous.

CHAPTER V.

Alluvial or Fresh-water Clays.—England.—Wealden Clay.—Coal Clays of Durham and Northumberland, and round Birmingham.—Essex Clays—on the Sides of Rivers, and on the Flats of the Sea-shore.—Scotland.—Clays of Berwickshire—East Lothian—Carses of Gowrie and Falkirk—on the Sea-shore and Sides of Rivers.—Cultivation of each Variety.—Rotations of Cropping.—Manures.—Draining, and Value of the Land.

Wealden Clay

Gets the name from "weald," a Saxon word, meaning a wood or forest, in allusion to the ground now occupied by the clay being formerly overgrown with timber. It is placed as the upper formation of the oolitic series, and is constituted of three groups, the Weald clay, the Hastings sand, and the Purbeck beds. The chalk and third sandstone, which overlie the oolite, had been swept away by a vast denudation, and the Wealden beds had afterwards been deposited by a fresh-water agency, as is evinced by the entire absence of marine shells, even of the kinds that are most common in similar depositions. What shells there are have most generally the forms of fresh-water or littoral kinds, and the plants are terrestrial or marshy, and not of marine origin. The remains of animals also indicate the littoral or marshy life of the huge creations of that period of the globe.

This deposit of clay in its character and aspect varies from a dark tenacious clay to that of a blue or gray calcareous marl of an earthy and friable texture. It contains occasionally layers of argillo-calcareous concretions, replete with shells of a noted shell-fish of rivers. The interior of these is usually filled by calcareous spar, which admits a slight polish, and the masses are wrought for ornamental purposes, and known as Petworth marble. The septaria of this clay are composed of a deep red argillaceous ironstone, and, with remains of fishes, occur in layers of two or three feet in thickness, in the upper divisions of the clay. The mineral contents appear to be limited to the specks of mica which occur in many of its beds, nodules of iron pyrites, and selenite. The shelly remains which are shown in the marbles are thought to indicate a lacustrine or fresh-water origin; but the evidence is not so thoroughly satisfactory as to place the matter beyond all doubt. It may be observed that these signs are exhibited by the marbles and not by the clays, and that the best proofs are of a mixed description, containing some kinds of aquatic birds, a fresh-water and marine turtle, a land tortoise, with fish teeth and scales. Hence it may be concluded, that marine and fresh water had by conjoined or successive operations produced this formation.

The Wealden clay occupies the low grounds of Kent, Surrey, and Sussex; in the first county forming a valley of five miles in breadth, from the Surrey border to the edge of Romney Marsh, and having a depth of 300 ft. It also occupies the valley running from west to east at the foot of the North Downs, which is watered by the Medway, the Eden, and the Beult. The whole southern border of the county of Surrey is occupied by the wealden clay, forming the broad valley at the foot of the green sand hills, and in some places forms the lower part of the south side of the hills. In Sussex, the Weald clay is the next important formation to the chalk. It joins the gault, and extends through the centre of the county, constitutes a low tract of five to seven miles in breadth, and presents no remarkable features on the surface, except in being favourable to the growth of oak in some places. Much iron was at one time manufactured in Sussex from the ironstone of the argillaceous beds ; but the want of fuel removed the operations to districts where coal is abundant. A small portion of the weald clay occurs in the eastern part of Hampshire. It is wholly unknown in the north of England.

In Dorsetshire, the Weald clay may be traced in the Isle of Purbeck, dividing the green and iron sands, but it thins off to nothing in the western part of that peninsula. In the Isle of Wight it may be observed holding a similar position, and having obtained a greater thickness; it may be traced following the green sands under the central chalky range ; and again, underlying the same formation in the southern range of the Undercliff. The formation never rises into hills of any height. In the central Weald of the southern counties, where alone it possesses sufficient thickness and extent to give any character to the general form of the surface, that surface is an uniform broad vale. The depth has been mentioned at 300 ft. in Kent ; in the Isle of Wight it appears not to exceed 100 ft. The inclination appears to be always parallel to the superstrata of green sand and chalk. The aluminous chalybeate spring of water in the Isle of Wight appears to have its origin in this formation.

The wealden argillaceous deposit presents to the agriculturist a soil of pale, cold, and retentive clay, naturally covered with woods, and of a productive quality that is very considerably below mediocrity. The prevailing arable character is a hard aridity and a meagre unctuousness, which denote a great want of mellow ingredients and exuvial mixtures. But the texture freely permits the land to be ploughed by the power of two horses, though the winter furrow is better done by three, and to the depth of seven or eight inches, which affords an ample quantity of soil for the summer operations. Two horses walk in tandem in the furrow, and the third on the unploughed land, and is a match for the two in the furrow, by having the long end of the main tree or the steel yard adopted in use. The other operations of working the land are conveniently done by two horses and the common implements. Root crops are not admitted by the wealden clays, and the process of summer fallow is indispensable. Farm-yard dung is the only suitable manure, and the young crops of grain may be top-dressed. The clay is not so wet or so very retentive as the plastic and London clays, and the draining may be at intervals of the distance of eight yards, with the drains slanting in the direction of the ridges at a greater or less angle, as the surface of the ground may direct. In many cases the ridging may be wholly laid aside, and the drains be laid by the fall of the ground. The depth of the drains to be as before mentioned, and also the filling with materials.

The rotations of cropping may be—

1st year . .	Fallow, dung and lime in 150 bushels.	3rd year	Clover.
		4th "	Oats.
		5th "	Vetches.
2nd " . .	Wheat.	6th "	Wheat.

The vetches may be of the winter or spring variety, and be consumed by sheep on the ground, which is sown with wheat from one ploughing. On the weaker clays of all denominations, the pasturage system is most earnestly recommended, as tending to give to clay lands the very thing they want, in the formation of loam by the decay of the roots and leaves of the grass, and by the rest of the land from cropping affording time to assimilate and amalgamate the materials. The decay of vegetable matters affords a manure that surpasses every fertilizing substance yet discovered.

The arrangement will be as under:—

1st year . .	Fallow, dung and lime.	4th year	Pasture.
		5th "	Pasture.
2nd " . .	Wheat.	6th "	Oats.
3rd " . .	Clover.		

Beans are not an appropriate growth on the wealden clays, though they may be introduced on the very best sorts of the land in the fourth and fifth year of the above rotations. But as the soil rarely admits a preparation in the spring for the beans, at least of any effect, the crop is in broad-cast, and had better be omitted. Peas are not advantageously used, but may be tried on the pasture furrow in the place of oats. In that case, a crop of oats will follow, and prolong the course into seven years; and beans may be substituted for the peas alternately in the course of cropping, which will give the land the benefit of the leguminous crops along with the pasturage of the grasses. The system is most admirable.

The list of grass seeds as under, per acre,—

Ray grass . . .	½ bushel.	Hand fescue . . .	2 lbs.
Cocksfoot . . .	¼ "	Red clover . . .	6 "
Meadow fescue .	4 lbs.	White clover . .	4 "
Catstail	4 "	Trefoil	2 "
Dogstail	4 "		

The wealden clay forms a transition from the marine to the fresh-water formations, and, though it is placed in the oolitic system, it must be held as a posterior formation to the clays which overlie the chalk, and which is itself a much later deposit than the oolites. As before observed, a denudation had bared the oolite of the superincumbent sandstone and chalk, and afforded the position for the wealden clay from the agency of fresh-water locations and estuary deposits. It would appear that both these agents have been jointly or separately employed in the production of the wealden argillaceous bed; the fresh water may have predominated, and given to the three constituents of the group a greater resemblance to the alluvial than to the preceding overruling agents of operation. It is largely accompanied by calcareous matter, which has been continued in diffusion, and is seen in the Purbeck beds, and in the Petworth and Sussex marbles. The stones are shelly and thinly laminated, but evince in their various forms and qualities the presence of the substance, and that its matter attended every formation. Sand is also very largely diffused both in beds and in mixture, and all the materials had descended from the state of schistus or shale to the condition of pulverization, whereby they were all prepared to form the sub-aerial deposit, or the cultivable stratum of the globe.

The Coal Clays

of Durham and south Northumberland overlie the coal mesaures of these two counties of carboniferous notoriety. The colour of the thin stratum is mostly black, but frequently the upper and under strata are of the same colour—a pale red hue, and sometimes whitish with sands intermixed. The most generally black colour may have proceeded from the shale of the coal, and have inherited from that deposit the quality inimical to vegetation, for the productive powers are very low, even when the clay almost immediately overlies the new red sandstone rock. In many places the depth is small before the coal is reached, and the approach to that deposit finds the shale or the undecomposed clay to be black and indurated, and regularly laminated. The cultivable stratum generally lies on deep beds of dry hardened clay, gravelly or sandy, according as the contiguity is fixed to the diluvial agency or to the detritus of the sandy rock. Where the rock is upheaved, good lands appear in clayey loams, while the surrounding low grounds are occupied by the sterile clays. The soil is very retentive of moisture, and, the absorbing stratum being shallow, the management is not a little precarious both in the spring and autumn. The total want of shells of any kind, and the absence of organic remains, consign these clays to the agency of fresh water in a tranquil state of operation; there are no contortions or disturbances, nor any visible interruptions of the sedimentary depositions. The formations have been little noticed, as they are not connected or associated with any stratified deposit, as the chalk or oolite, nor are they conducive to the illustration of any superincumbent or surrounding formations. The carboniferous limestone appears on the high boundaries of the concavity of the coal beds, but seems wholly unconnected with the formation of the soil.

The land very generally bears a near resemblance to the wealden clay; it can be wholly tilled by the power of two horses, and by the common implements—the plough, harrow, and roll. The winter furrow is best of the depth of six to eight inches, and will require three horses. The texture of the soil excludes any root crops, and a bare summer fallow must be adopted. The quality of the land generally is below the growth of beans, and is not favourable to peas or vetches. Oats are grown, but not advantageously, and wheat, even in the poor returns that are obtained, forms the staple production on these lands. The four years' course of cropping is—

1st year	Fallow.	3rd year	Clover.
2nd „	Wheat.	4th „	Oats.

This has been followed for a length of time, and with much injury to the land, and peas have been introduced :—

3rd year	Peas.	4th year	Oats.

Thus omitting clover, and using it only once in eight years. No very great benefit has happened from this change, and, as beans and peas must be used in broad-cast, the benefit of the half-fallowing cultivation of these plants is not obtained. The pasturage system may be brought into operation with great advantage on these lands; the matting of grassy roots which covers the surface, affords a decomposing nutriment to the succeeding crop of oats, and the rest which the land enjoys tends to invigorate the powers of the soil. Thus in five or six years—

1st year	Fallow.	4th year	Pasture.
2nd „	Wheat.	5th „	Oats.
3rd „	Clover.		

Or—

5th year	Pasture.	6th year	Oats.

These lands are wonderfully improved by these courses of cropping, and sheep thrive well on clay grounds, provided the herbage be fresh and sweet. This object is attained by the regular renewal of the pasture by fresh seedings of the cultivated ground. Any damage sustained has arisen from old mossy herbage. Vetches, peas, and beans are sown for the use of the farm, but form no part of the beneficial cultivation. Being in broad-cast, the tendency is to scourge, and not to improve; hence their use is very limited. The grass seeds to be used per acre are as under :—

Ray grass . . .	½ bushel.	Dogstail	2 lbs.
Cocksfoot . . .	¼ „	Red clover . . .	6 „
Meadow fescue .	2 lbs.	White clover . .	4 „
Catstail	2 „	Trefoil	2 „

Farm-yard dung and earthy composts only are useful on these lands, with the usual top-dressings on the spring crops. The draining of these lands must be at the distance of five yards, the drains being placed in the furrows, or slanting on the ridges, cut to the depth, and filled with the materials before directed.

In the midland counties, and around Birmingham, the colour of these clays is more red than the last-mentioned varieties, and the quality somewhat better. But their general nature compels the same management in every respect, as the resemblance is very great in the dry aridity of the ploughed soil, and the very repulsive quality to any root crops, or leguminous plants. Where they are introduced, the broad-cast cultivation rather forbids than recommends them. Being cleared, by fallowing, of the weeds of annual and perennial life, that condition is better preserved by the land remaining in grass for two or three years than by constant cropping, which encourages the germs of life of every denomination to spring into existence. Hence the great benefits that have been derived from this system whenever introduced and properly performed; whenever similarly managed, it has been attended with similar results.

A very considerable part of these clay lands, in the north of England, lie in serpentine ridges of very irregular width, often six or eight yards in breadth at one end and two or three yards at the other, being wide and narrow in contiguous ridges without any regularity, and the wide end of a ridge often terminating in a narrow point in the middle of the length of the field, or of the direction of the ridges. In the larger fields, the ridges often form divisions that lie in very different directions. Much inconvenience, in the loss of time and frequent turnings of the implements, attends the cultivation of these awkward allotments of the ground; attempts have been made to straighten the ridges, and, in many cases, have been attended with a lasting damage to the value of the land. The failures have arisen from not attending to the circumstances of the case which govern the results, as in all other points where they so very powerfully come into operation. From the long-repeated gathering of the ridges, the substratum has been raised to a convex shape as well as the upper, and the intervening furrows are deeply sunk between the ridges. New ridges being placed in a slanting direction over these heights and hollows, were unequal in the declivity; the heights intercepted the flow of the water, which stagnated in the low places, and reduced the contiguous ground to a state of mortar. A great mistake was also committed in making the new ridges too wide, as not many ploughmen are capable of rounding a ridge to the proper convexity beyond the width of twelve feet. In new formations, the proper width is nine or ten feet. Where the old ridges are nearly though not altogether straight, not very highly raised in the centre, and lie all in one direction, the new formation is not very difficult; but in the awkward forms that have been mentioned, the process is matter of serious consideration. The first requisite is to level the surface so as to get a base of operation, and it has been proposed to employ the spade, and perform the work at once. But the cost would be immense, and wholly condemn these poor lands, as the upper soil must be laid aside, and again replaced after the substratum of clay has been levelled by the digging and movement of the bed.

A very cheap and effectual method of levelling these high ridges of unequal widths and crooked longitude, consists in gathering by the plough, in the hollow furrows, a small ridge during the fallowing of the ground, which may be commenced of the width of four to six feet, and be increased by two or three furrows of the plough in each succeeding fallowing of the land. By degrees these new ridges will be raised to the height and width of the old ones, the ground will be levelled, and then a new formation and direction of the ridges can be effected without any damage either to the upper soil or to the underlying stratum which acts as the drain to the water from the land. In making new formations the width of the ridges may be five yards, in order to suit the frequent drains in each furrow, which are adapted to these thin clay lands, as they quickly remove the water from the soil. The merits of this system of frequent draining have already been discussed.

The writer of this treatise on clay lands practised with much success the above preparatory mode of altering the awkward surface of clay soils in south Northumberland, and is therefore able to recommend it from experience, which is the sure ground of all practical knowledge. During the first gatherings of new ridges, much aid is derived from harrowing the ground across, as the clods are pulled into the hollow places, and afford soil to the next ploughing.

Essex Clays

are compounded of the plastic and London formations in the inland parts of the county, and on the shores of the estuary of the Thames assume the alluvial characteristic, and overlie the older deposits. The intermixture of the two marine formations above mentioned has produced a very large modification of the respective qualities of the argillaceous earths: the very obdurate adhesion and viscous clamminess have been very much reduced, even in those places where the primary formations are allowed to exist. Still the quality is hard and stubborn, but admits many advantages beyond the original beds of which it is formed. It would seem that the receding waters had left on higher grounds the suspended materials, which were impregnated with the respective qualities of the acting operators, and that in the further stages of the retreat of the watery elements, the affinities of the ingredients had changed, and new combinations had happened, which, along with the subsequent operations of different powers, have exhibited many degrees and varieties of elements and materials, but still bear the evident stamp of the original type. These remarks apply very strongly to the Essex clays, which, being reduced from the nature of the marine formations, are correspondingly increased in their productive quality, exactly as they recede from the plastic obduracy of the lower tertiaries. The shells and organic remains are less numerous, and the whole deposit marks a stage of large advancement from the marine to the alluvial epochs.

The clays of Essex are capable of being cultivated by the common implements, with the power of two horses. The winter furrow is best done by three horses, as in the case of all clay lands, and of the depth of six to eight inches. Root crops are wholly forbidden by the clayey soil, and the summer fallowing of the land becomes the preparation for the crops of the rotation. The process requires three or four clean earths, exclusive of the winter ploughing; which will be three earths during summer, one ploughing to cover the dung, and the seed furrow. In some cases the grubber will save a ploughing, and even produce more effect.

Some parts of the land allow a spring preparation for beans, by reversing the winter ploughing and working the land lengthwise and crosswise by the grubber; it is then drilled by the common plough, dung applied, beans sown, and the drills reversed. The surface is also deeply harrowed, and lightly scarified on the winter ploughing, the beans being dibbled on the alternate furrow slices, or sown by the ruts of the drill machine across the ploughing. It may be better to open ruts on the harrowed surface by one-horse ploughs at intervals, which will admit the hoeing and scarifying of the crop; the beans are sown broad-cast, when the seed falls into the ruts and are covered by harrowing. But unless the crop is sown in wide intervals, the benefit of the bean crop is not conferred upon the land. Peas and vetches do not grow advantageously on the Essex clays; they form a broad-cast catch crop, and are not entitled to a standard position in the rotation. They are generally much too thinly sown, grow in a straggled manner, and fill the land with weeds. But they are useful in a minor degree.

Farm-yard dung is the only manure with which the Essex clay will reciprocate, along with lime and earthy composts. The quantity of lime should not be under 200 bushels on an acre, with as much farm-yard dung as can be got. The young crops of all kinds can be top-dressed in the spring with the usual pulverulent bodies. The frequent draining may be done at eight yards apart, the drains slanting with the ridges or fall of the ground, cut to the depth, and filled with materials as before described.

The most suitable rotations on the best lands are—

1st year	Fallow, dung and lime in 200 bushels.	4th year . .	Oats.
2nd „ .	Wheat or barley.	5th „ . .	Beans, drilled and dunged.
3rd „ .	Clover.	6th „ . .	Wheat.

This is the common rotation over Britain on clay lands of the best quality; it may be varied in two ways—

3rd year	Beans.	Or—3rd year . .	Vetches.
4th „	Barley.	4th „ . .	Barley.
5th „	Clover.	5th „ . .	Clover.
6th „	Oats.	6th „ . .	Oats.

The vetches, being consumed on the land by sheep, manure the ground, and saves the labour of dunging the beans, which is often troublesome. Unless the land can be wrought in the spring by the plough and grubber for the beans, and these drilled at wide intervals, which admit of horse-hoeing, the land does not obtain the benefit of the crop, and the plant sinks in value. The narrow intervals from dibbling the seeds on the furrow slices, and the sowing by drill machine or by rutting with small ploughs, only admit the hand-hoeing of the crop, and light scarifying of the ground, which, though far better than the broad-cast system in loosening the soil and eradicating the weeds, is yet very imperfect, as the scarifying cannot be deeply done, from the furrows not having been broken by cultivation. It can only move a few inches of the pulverized surface, which does not penetrate the ground, and therefore the working of the intervals is too shallow, and effects but little benefit.

The inferior clays of Essex require an easier rotation, and less scourge cropping, thus:—

1st year	Fallow.	Or—1st year . . .	Fallow.
2nd ,, ...	Wheat.	2nd ,, . . .	Barley.
3rd ,, ...	Beans.	3rd ,, . . .	Vetches.
4th ,, ...	Oats.	4th ,, . . .	Wheat.
5th ,, ...	Vetches.	5th ,, . . .	Clover.
6th ,, ...	Wheat.	6th ,, . . .	Oats.

The vetches are best used in the fourth or fifth year, when the crop, being consumed on the ground by sheep, manures the land for the wheat, which enters twice into the rotation; or only once on weaker lands, by sowing barley on the summer fallow.

The pasturage system before recommended may be well used on the weaker clays, thus:—

1st year .	Fallow.	4th year	Pasture.
2nd ,, .	Wheat or barley.	5th ,, ...	Pasture.
3rd ,, .	Clover.	6th ,, ...	Oats.

The seeds of grasses as under—

	Per Acre.		Per Acre.
Ray grass . . .	$\frac{1}{2}$ bushel.	Hand fescue . . .	2 lbs.
Cocksfoot . . .	$\frac{1}{4}$,,	Red clover . . .	6 ,,
Meadow fescue .	4 lbs.	White clover . .	4 ,,
Catstail	4 ,,	Trefoil	2 ,,
Dogstail	4 ,,		

The pasturage may be shortened by one year, and peas or vetches take its place, thus:—

1st year .	Fallow.	5th year .	Oats.
2nd ,, .	Wheat or barley.	6th ,, .	Vetches or peas.
3rd ,, .	Clover.	7th ,, .	Wheat.
4th ,, .	Pasture.		

The clay lands of Essex produce the best qualities, and also the most abundant quantities, of wheat and beans that are grown on any soil in England. The texture of the land is a medium between the marine tertiary deposits and the alluvial formations; it passes from the extreme viscid clamminess of the former, and does not reach the weakness of the latter that is caused by the minute separation of the particles from the abstergent action of the waters. It does not match the fertility of East Lothian, but the favourableness of the climate perfects a quality of the articles that is equal, if not superior, to the productions of that celebrated county. The soils of Essex are wanting in the loaminess which allows the very superior cultivation of beans in East Lothian, and consequently the crops are not so large, nor the land so valuable. The last-given rotation of cropping, which joins, in the course of seven years, the pasturage farming along with beans and wheat, offers many advantages that have not yet happened in the farming of clay lands. Barley being sown on the fallow very much promotes by its tilth of the land the success of the grass seeds, and beans, vetches, and peas, being used in the sixth year, either in the alternate rotations or in shares of the land in every course, the scuffled surface of the gratten presents a very favourable ground on which to spread the lime which the land is destined to receive. And the two years in grass rest and recruit the soil, and at the same time pay their regular share of the expected value. The rotation claims much merit, and deserves every recommendation.

Clay Lands

of the alluvial kind are found on flat extents near the sea-shore, chiefly near the mouths of rivers and estuaries, round the whole coast of England. These lands, as Romney Marsh and Pevensey Level, are used in grass, and do not come under the notice of cultivators; but on the sides of rivers in the interior of the country, clay lands are found which forbid the use of root crops, and at the same time are very sparingly productive in the returns of wheat and beans, even where they are used on the best qualities of ground. The swing plough, with the power of two horses, is capable of tilling these river-side alluvial clays, the bare summer fallow is necessary, and half-rotted farm-yard dung is the only fertilizer that can operate any benefit upon the texture of the land. The frequent draining is done at the distance of eight yards apart in the trenches, sharply slanting in the direction of the ridges or the fall of the ground; the drains are cut to the depth, and filled with the materials, before directed. The best cropping is—

1st year . .	Fallow, dung and lime in 200 bushels.	3rd year	Clover.
		4th „	Oats.
		5th „	Vetches.
2nd „ . .	Wheat or barley.	6th „	Oats.

On inferior soils—

1st year .	Fallow.	4th year	Pasture.
2nd „ .	Oats or barley.	5th „	Pasture.
3rd „ .	Clover.	6th „	Oats.

This last rotation requires a high inland latitude and a late climate, to which the grain crops that are used must be conformed.

Scotland

contains clay lands of a value very superior to those of England, and which are all of the fresh-water formation, as that country contains no stratification above the first or old red sandstone, which supports the limestone and the few coal beds that occur. The whole cultivable lands are alluvial beds that rest upon the primitive rocks, which are surrounded in some places by wackes and the sandstone, which support the most fertile districts. Entering the kingdom from the south, there occur, immediately on crossing the Tweed,

THE MERSE CLAY LANDS,

which cover the low part of Berwickshire, and stretch from the sea inland, along the course of the river, for about twenty miles, while the average breadth may be six or eight miles. The formation rests upon the old red sandstone that has been derived from the clay-slate of the Lammermuirs, which, both on the north and south sides of the range, afford the materials of the stratified deposits. In the western parts of the county the eruptions are high and very large of the trap rocks, which always support good soils, and more dry and friable than the lower deposits on which the waters had congregated for a longer time. In that district the clays are more easily wrought, and are more valuable where the climate is favourable, and not too inclement for the growth of their valuable products.

The Merse forms the half of a basin or circle, of which the straight line runs along the river Tweed, and the curve describes an arc, from the meeting of the clay and turnip lands towards Kelso, by the foot of the Lammermuir Hills, in the north and east, to the mouth of the river at the town of Berwick. The lower part of the semicircle is very flat on the surface; but the ground rises gradually all round the arc, and the land passes into different qualities. The ground is much higher on the south side of the river, and is much of the same nature for a shorter distance to the interior. The clay is mostly black in colour, and comparatively loose in the texture, though very indurated in the bottom. It is cultivated by the swing plough, with the power of two horses, and by the other common implements of tillage. The summer fallowing of the land must be practised, and farm-yard dung is the only manure which is useful to the soil. The draining is done at the distance of six to eight yards, with the gutters placed, cut, and filled, as before directed.

The general quality of the Merse clay lands is rich, producing wheat in large abundance, though beans are not very much used, owing to the climate being rather unfavourable for the growth and maturity of that plant. Not that the plant does not grow abundantly both in straw and pods; but the general circumstances of the geographical situation do not warrant a very large cultivation of the crop. But they are used on the very best lands, and the returns are large. The best qualities of land are found in the low eastern corner of the clay district, which is formed by the convergence of the river Tweed and the range of Lammermuir Hills. The undulating surface of the interior range of the semicircular country as it rises to the hills on the north, and on the west to the turnip soils of Roxburghshire, presents a great variety of land, mostly in cold thin clays of an inferior quality, but still very fairly productive. On the best sorts of lands the six years' course is not exceeded.

1st year . .	Fallow, dung and lime in 200 bushels.	3rd year	Clover.
		4th „	Oats.
		5th „	Beans.
2nd „ . .	Wheat.	6th „	Wheat.

The following course may be eligible in some cases, and has been before much recommended :—

1st year . . .	Fallow, dunged.	4th year	Oats.
2nd „	Barley.	5th „	Beans, with lime.
3rd „	Clover.	6th „	Wheat.

Or—

4th year . . .	Pasture.	6th year . . .	Beans, limed.
5th „ . . .	Oats.	7th „ . .	Wheat.

It requires a degree of loaminess in the soil to receive the barley plant, and it will be difficult to gain admittance for pasturage on these strictly corn lands. The most waxy and strongest of the clay soils may not admit this course, and the rotation of four and six years will be used. Strictly corn lands are distinguished by the capability to produce matured crops in succession, without being recruited by rest.

On the cold clay lands of inferior quality, the pasturage system becomes most eligible, though the constant cropping rotation is yet followed without known damage to the land or to the profits. The pasture may be in one or two years, thus :—

1st year . .	Fallow, dung and lime.	4th year .	Pasture.
2nd „ . .	Wheat.	5th „ .	Beans, vetches, or peas.
3rd „ . .	Clover.	6th „ .	Oats.

Or—

5th year . .	Pasture.	6th year . .	Oats.

Grass seeds, as under,—

	Per Acre.		Per Acre.
Ray grass . . .	½ bushel.	Dogstail	4 lbs.
Cocksfoot . . .	¼ „	Red clover . . .	8 „
Meadow fescue .	4 lbs.	White clover . .	4 „
Catstail	4 „	Trefoil	4 „

The land sown with beans receives the usual preparation for being drilled and dunged, and in wide intervals, which admit of the perfection of the bean culture; yet the crop is often seen in narrow distances, which only admit of the hand-hoe, or a very light scarifying, which does not move the ground to the depth necessary for pulverization. As the wheat thrives best after beans, the plant is approved wherever success is at all probable, though a richness is required in all clay lands for the production of beans; and it requires a suitable cultivation of the soil and arrangement of the crops to correspond with the natural adaptation which is seen to prevail in other respects. This consideration claims, and obtains a very large place in every step of agricultural advancement.

East Lothian

is the county of Scotland most celebrated for its system of cultivation, the bulk of produce, and the acreable value of the land.

It forms the range of country north of the Lammermuir Hills, and extends to the German Ocean, and westward to the neighbourhood of its metropolis. The soil is mostly clay of various qualities, lying on vast alluvial beds, which are superimposed on the old red sandstone that surrounds the mountains of the primitive and transition strata. A large extent of trap rocks is projected upwards in the extreme north part of the county that borders the curved lined of the sea, and supports a red rolling clay soil of fertility unequalled by any lands in Britain. In some places gravels are intermixed with the clay, and the fertility is increased. The swelling grounds rise into turnip soils in the interior of the county, and in the western and southern parts red clay lands occur, which are stiff and waxy, dry and arid, and rest on the lowermost sandstone. The formation everywhere shows a fresh-water agency, and a very extraneous and imported bed of materials. The sea cliffs exhibit many alternations of very dissimilar substances, which are not found in the inland parts, and in these localities there are found many diversities and irregularities, from the clay to the loam of the most recent formation.

Trap rocks are allowed to be formed of ancient lavas, which are the production of volcanoes, by the complete fusion and amalgamation of the heterogeneous mass of materials that had been collected. Lavas are most exceedingly fruitful, which may arise from the temperature retained from the heat of the fusion by burning. Trap rocks may be possessed of a latent heat from that source, and communicate a high temperature, or at least some degree of warmth, to the superimposed clay soil, and thus increase the fertility, as temperature is a great source of productiveness. This supposition may account for the very great superiority of the trap clays in that county over the other deposits, and it is not more improbable than many other geological speculations.

The clays of East Lothian are all ploughed by two strong horses with the swing plough, and by the other common implements of tillage. Summer fallowing of the land is invariably practised, and beans are cultivated to the highest perfection in Britain. The climate is early, and favours the maturity of the plant, and also the spring cultivation of the land. The winter furrow is reversed by the spring ploughing; the grubber is employed lengthwise and crosswise, which, with some harrowings and rollings, enables the land to be drilled at the distance of 27 in. The farm-yard dung in a half-rotted state is laid in the hollows, the beans are sown by a barrow, and the drills are split to cover the dung and seed. The horse-hoeings and hand-hoeings are done in succession till the growth of the stems prohibits any further interference. A crop of beans on the trap clays of East Lothian, treated in this way, forms, in the month of July, one of the finest sights that any country can afford.

The best rotation is—

1st year . . .	Fallow.	4th year . .	Oats.
2nd „ . . .	Wheat.	5th „ . .	Beans, dunged.
3rd „ . . .	Clover, in hay and pasture.	6th „ . .	Wheat.

This is an old and favourite rotation, and no better has yet been found.

Very varied qualities of clay lands are found overlying the coal formations in East Lothian, and on the conglomerated rocks which occur on the borders of the primitive range, from which the inferior deposits are derived. The remoteness from the sea-shore induces a late severity of climate, and these two causes compel a different arrangement of cultivation. The best systems are—

1st year . .	Fallow, dung and lime in 200 bushels.	3rd year	Clover.
		4th "	Pasture.
		5th "	Beans.
2nd " . .	Wheat.	6th "	Wheat.

In the highest situations the pasture may be prolonged, and oats are the scourge crops. Peas are used only on the turnip soils, and vetches in the quantity consumed by the working horses, and not for a rotation crop. The latter application may be wanting more from the non-consideration of the utility of the plant than from any intrinsic demerit of the vegetable.

The course of six years, above stated, is applicable to lands of the very best quality. Where a loaminess of the soil prevails, and the quality of the land is a shade weaker, the following rotation will be very useful, and is even recommended :—

1st year . .	Fallow, dung and lime.	4th year	Pasture.
		5th "	Oats.
2nd " . .	Barley.	6th "	Beans.
3rd " . .	Clover.	7th "	Wheat.

As the land recedes in quality the pasture is extended, the use of beans declines, and vetches come into cultivation. Peas are not eligible on weak clay lands, or under late and weeping climates.

Very much of the successful agriculture of East Lothian is owing to the dry and early climate, which allows of spring preparation of the land for beans, and the most complete performance of the summer fallowing process. The general character of the land is excellent, not very wet, but still much benefited by furrow draining. That improvement is now settled as being the best done in a drain placed in each furrow of the 18 ft. ridges, at the depth of 2 ft. to 2½ ft., and filled with materials of stones, or a tile with stones to 1½ ft., thus leaving 1 ft. for top soil. Repeated trials have settled this system of draining. Subsoil ploughing has been abandoned, as producing no difference in fertility, or at least not sufficient to cover the expense.

Ray grass and red clover are the only herbaceous plants that are sown in East Lothian for the hay crop, and the following aftermath that is used in pasturage or in soiling. It was found that no addition to the latter-math was gained by sowing portions of the cocksfoot, fescue, and catstail, as the growth of these plants does not proceed in one year to equal the ray grass, which yet holds the undisputed pre-eminence in the qualities of ready attachment, produce, and maturity of seed, and all on the greatest variety of soils. For the use of one year, as in the rotations of constant cropping, no grass plant can be compared with it.

The quantity of seed must be large when only two plants are used :—

Per acre	Ray grass	1 bushel.
	Red clover	10 or 12 lbs.

The Carse of Gowrie

forms a part of the county of Perth in Scotland, stretching along the north bank of the river Tay, between the towns of Dundee and Perth, to the distance of about twenty miles, and the breadth being about three or four miles. The soil is a rich clay of the alluvial deposit, which rests on the old red sandstone that occupies the low grounds at the base of the primary range, and stretches in a broad belt across the island from the German Ocean at Montrose to the Atlantic at Glasgow. The western parts have been much disturbed by large eruptions of the trap rocks, as they are seen in the Ochill Hills, which pass under various names in the different districts which they traverse. The clay of the Carse of Gowrie shows no evidence of any marine presence, and consequently constitutes a fresh-water formation. The quality of the soil is not equal to the trap clays of East Lothian, but it exceeds any other argillaceous deposit, and holds the second place in the value of cultivated lands.

The summer fallowing of the land is required as the foundation of the system of cultivation, which is done in every stage by the swing plough with the power of two horses ; and this is provision enough to perform all the other operations through the rotation of crops. As in the case of all clay lands, farm-yard dung alone acts as a manure, and the usual top-dressings may be applied in the spring on the young crops. The draining is best done in the furrows of 18 ft. ridges, cut to the depth, and filled with materials as before described. The lands are not very wet, but are much benefited by furrow draining, and by surface cuts of depth and width. This latter way has been long practised, but is now superseded by the permanent effects of tile and stone drains.

The rotations of cropping on the clay lands of Gowrie differ little or nothing from those practised in East Lothian, the six and seven years' course being adopted on the very best lands, and the pasturage on the inferior qualities. Wheat and beans are grown in large abundance, and the quality of each grain is very good. Peas and vetches are not in much use, and are a stray crop rather than fixed productions. Both plants are great improvers of land when the crop thrives, and most pernicious when it fails. The late springs of the northern climate of the Carse of Gowrie do not allow any preparation of the land for beans, and the crop is sown in broad-cast. This is a very great drawback on the value of clay lands, from which few are exempt, except the best clays of East Lothian. The soil of the Carse of Gowrie also wants the certain degree of loaminess that permits the spring stirring of the land. It may be rutted as before mentioned, and the beans sown in narrow drills, which are preferable to broad-cast.

The Carse of Falkirk

is a part of the county of Stirling in Scotland, occupying the banks of the river Forth below the town of Stirling, in the downward course of the river to the estuary expansion of the waters. The land is an alluvial deposit on the old red sandstone, the soil being a bluish clay mixed with sand. The fresh-water agency is established by the total absence of any marine exuviæ, and the want in the texture of the soil of the viscous clamminess which attends the formations that have proceeded from sea water. The aluminous quality still remains in a degree that is sufficient to distinguish the character of the land, and its nature demands the common treatment of argillaceous textures. The quality is below the Carse of Gowrie and East Lothian, and the course of cropping must be less severe. The summer fallow prepares the land by the swing plough and two horses, and the other operations are done by the same power. The draining is done as before directed.

The short course of four years necessarily deviates into six or seven years, as before stated, and a rotation of five years may be thus :—

1st year . .	Fallow.	4th year .	Beans.
2nd „ . .	Wheat.	5th „ .	Wheat or oats.
3rd „ . .	Clover.		

Or, by introducing peas and vetches,—

4th year . .	Oats.	6th year .	Wheat or barley.
5th „ . .	Vetches.		

The vetches should be consumed on the ground by sheep,—a practice not known in that country; peas may be substituted, and the surface scarified and limed for the crop of wheat or barley. Deviations may be effected in this way, so that wheat or any other grain crop does not occur twice in the rotation.

The West of Scotland

contains some considerable extent of clay lands on the flat shores of the counties of Ayr and Renfrew, which are alluvial and very mixed depositions lying on the sandstone, the rock that is next the primitive formations, which everywhere form the geological basis of Scotland. In many places the alluvium overlies the gneiss and granite, and covers the sandstone in the hollows and declivities which mark the transition of the rocky strata. These clays are weaker in quality than the formations of that kind on the eastern coast of Scotland; the aluminous adhesion is more faint, and the viscous texture is less concentrated. The lands are easily tilled by the power of two horses in a swing plough, and the other operations are done by the common implements. The rainy climate is unfavourable to the growth of beans, and wheat is precariously cultivated. But the latter crop occupies the fallowed grounds, and beans are mostly an interloping crop, and do not confer the benefit of their use as a drilled pulverizer and enricher of the ground. Even on the best grounds pasture is most useful, and may be varied with the grain plants, thus :—

1st year .	Fallow, dung and lime in 200 bushels.	3rd year	Clover
2nd „ . . .	Wheat.	4th „	Pasture.
		5th „	Beans.
		6th „	Oats.

Or—

5th year	Oats.	7th year	Barley.
6th „	Beans.		

Vetches and peas can be little used; beans are drilled, but the climate prevents the full benefit being derived. The half-fallow crops, as peas, vetches, and beans, require a dry and early climate for the development of their value, and the west coast of Scotland is humid and very wet, and almost prevents the performance of fallowing, except in the most favoured situations. The benefits of the summer fallowing of the ground are confined to the short course of four or five years, and cannot be extended to six or seven, which requires the assistance of a leguminous cultivation that is denied by the climate in the imperfect growth of the plants. The extension is practised in some places, but its adoption is not general. The draining of the land is to be done as before directed.

THE SEA-SHORES OF SCOTLAND,

especially on the eastern coast, show quantities of clay lands of greater or less extent, as the interior country rises in height. The sides of rivers are covered by similar depositions of various qualities, which are all reckoned to be alluvial formations, as they contain no incontestible signs of marine agency in the exuviæ of shells, nor any organic life. But a probability may be entertained that the formations are partly marine, as the viscous clamminess is very considerable; and the absence of marine life may have arisen from the shorter period of suspension, and from a sudden relapse of the waters, which carried away the living specimens of organization. The clammy texture prevents the use of root crops, and a summer fallow becomes the preparation of the land for the rotation that follows. In early localities near the sea-shore, wheat is used on the fallow tilth, and beans are taken as a catch, and sometimes as a partial fallow crop; but the practice is not general. Thus:—

1st year . .	Fallow, dung and lime in 150 bushels.	3rd year . .	Beans.
2nd „ . .	Wheat.	4th „ . .	Barley.
		5th „ . .	Clover.
		6th „ . .	Oats.

Or, in pasture,—

6th year .	Pasture.	8th year . .	Oats.
7th „ .	Oats or pasture.		

In the interior of the country, on the sides of rivers, wheat does not prosper, and even barley is not eligible; and thus oats become the crop on the fallowed lands, and also on the grass pastures when ploughed for cropping. The draining of the land, where necessary, is to be done as before directed.

Except in some few warm situations where the land is of good quality, the pasturage system is the most eligible, as the rearing of black cattle is the most profitable mode of converting the ground into value. The districts of East Lothian and the Merse, and the Carses of Gowrie and Falkirk, alone produce beans in the abundance that incites to their cultivation; on the few spots of clay lands that have been mentioned the plant is sometimes used, but in a stray manner, and not fixed in any regular course of cropping. The climate from the Carse of Gowrie northwards does not favour the growth and maturity of legumes; the springs are cold, and the autumns late, and the general consumption of the country does not encourage the production of the seeds for farinaceous purposes. The advancement of agriculture has fixed the adaptation of the growths that are suitable to the climate, which, even more than the soil itself, influences the usages and regulates the productions.

There are no clays of marine formation in Scotland, and all the lands of that country are alluvial beds that overlie the primitive or transition rocks. The stratification of the kingdom ceases with the commencement of the carboniferous series in the old red sandstone and the overlying lime rock, and some few coal formations; all the upper deposits, if they ever existed there, have been wholly swept away by changes that have succeeded their formation. The agricultural geology of that country is more simple and less complex than that of England, especially of the southern parts, where all the formations exist that are found over the world, from the lowermost granite to the upper stratified chalk; and hence through all the gradations of marine and fresh-water tertiaries to the sub-aërial deposit of the most recent alluvium. The full development of all these strata in rocks, shales, limes, coals, clays, and sands, presents a great variety of surface grounds that require a very different cultivation, and also varied tools or implements of operation. In Scotland there are only two designations of land, the fresh-water clays, and loams of very many kinds and qualities, varying from clayey soils that grow turnips, to the weakest sands that are worth cultivation. The latter soils are wholly mild from the agency of fresh water, and differ from the green and iron sands of England, which become hardened and encrusted, and corrode and devour all organic substances. Hence the great success of Scotland in the adoption of regular rotations of cropping, and in the use of the same implements over the whole kingdom. The similarity of the soils permits the same implements, and the climate allows the same course of cropping, with some local enlargement of pasturage, and diminution and adaptation of grain crops.

CHAPTER VI.

Change of Clay Soils into Loams, by means of being dug by the Spade and mixed with hot Lime.

The baffling qualities of clay as a cultivable earth arise from the large reception and obstinate retention of water by the aluminous base, and the very anomalous natural property of contracting by heat, and conducting caloric in a degree that is almost the lowest of the graduated scale of metals and earthy bodies: gold being at the top of the list in 1000, clay is at the bottom in 11·4. The earth imbibes fifteen times its own weight of water without dripping, and retains it with great obstinacy; and this condition forms an almost insuperable barrier to the working of the land in cultivation. The quality of contracting by heat is still more baffling to the cultivator of the soil, for the lumps of earth become hardened, and resist every mode of reduction. Expansion is so general an effect of heat, that there are only two known exceptions, viz., in clay, and in water to a certain limited range of temperature. Baked clay is much contracted, and remains in its lessened dimensions. The expansion of bodies by heat proves the mutual repulsion of their particles; but this limits the repulsive energy of heat to insensible distances. Experiments have failed to show that the repulsive power of heat was exerted at sensible distances, as the motions may have arisen from the formation of vapour at one end of the globules of water that were moved along the fine wires. Cohesion is the force that is opposed to expansion, which is least in solids, where the cohesion is strongest; it is more considerable in liquids, where the cohesion is greatly weakened; and it is greatest in gases, in which cohesion is wholly overcome.

The expansion of bodies by heat, and their contraction on the reduction of the temperature, would show that the atoms of bodies are not in absolute contact. In fact, we may suppose them surrounded by "atmospheres" of heat which prevent, by the repulsive energy of caloric, their absolute contact, whilst the force of cohesion limits the diffusive influence of the contained caloric. In some, the superior force of cohesion gives rise to solidity. When more heat is introduced, the cohesion is weakened, and the body becomes a liquid; and a further addition of caloric destroys cohesion altogether, separates the atoms, and the body becomes a gas.

The specific caloric, or latent heat of clay, is very small, and, water being 1·, it may be placed at 0·1200, and ranks among the oxides. The cohesion of the particles is much too powerful for the repulsive energy of the specific caloric, and the small quantity of the latter constitutes a weak affinity or property for combining with an indefinite application of the peculiar element. Water contracts to the downward temperature of 42°; but whilst passing from that point down to its freezing point, it continues to expand gradually, until converted into ice. When a body changes its form of existence, its capacity for heat is also changed; when a solid is melted, its capacity is increased, and the specific heat of the same substance is still further increased when it is converted into vapour.

Heat is a peculiar property that causes sensation, and caloric is the cause of it. The necessity of heat to the promotion of vegetative growth is too well known to need any arguments or demonstration to establish the truth; the want of it causes sterility, and too much induces first, after flaccidity in the growth, and at last a scorched barrenness. A medium temperature is the condition that is suitable to all beneficial growths. For this purpose it is necessary that heat be not only communicated, but that it be retained by bodies that are capable of administering it in the proper channels of distribution for vegetable use. The diffusion of heat is equally necessary with the presence of it, and the permanent residence of it, or what is called the specific caloric of bodies, constitutes a property of the very first importance for agricultural consideration. Some bodies conduct caloric too freely, and are overheated, but the property is soon expelled, and gives way to an opposite extremity of affection. Others deny a passage, or even an admission, to caloric, and consequently remain in a condition that is very unfavourable to vegetable life. These variations are deserving the most minute and serious investigation.

The facility with which bodies conduct heat is not exactly in proportion to any of their sensible qualities, but is more nearly in the direct ratio of their density than any other quality. This may be ascribed to the greater intensity of the repulsive energy of the atmospheres of caloric surrounding each particle of dense bodies, by reason of their greater proximity, conveying each fresh addition of temperature with greater celerity through such substances. But if heat be reckoned a material agent, this quickness of conducting power may also be modified by the different degrees of affinity between caloric and each kind of matter. Heat passes less readily through solids when they are of a spongy or porous texture, than through those that are more dense and compact. The portions of air become entangled in the pores, which seem to prevent the communication of heat. A repulsive power is an inherent quality of heat, and is the cause of its diffusion among bodies; but the manner in which it is distributed, and the particular law which it follows in passing from and entering into bodies, seems to depend upon a different principle, or at least to be modified in a way that cannot be referred to repulsion. A double operation may be supposed; that heat escapes from one body in consequence of the repulsive power that exists between its particles, while at the same time it is attracted by the particles of the body which it enters. As a general principle, it may be stated that the densest bodies are the best conductors; but to this rule there are many exceptions. But so many instances confirm the rule, that when the ratio seems not to be strictly maintained between the density and conducting power of bodies, the interference of some other principle must be attributed. A difference in the state of aggregation increases or diminishes the conducting power of a body in proportion to its density, or to the contiguity of its particles, without its having undergone a chemical or any other physical change. Solid iron and wood are better conductors than filings of the metal or sawpit dust. Clay, being an oxide of a metal, is a worse conductor than solid bodies, besides its spongy porousness being adverse, as above noticed.

The conducting power of bodies depends principally upon three circumstances: it is affected partly by the mechanical relation of their particles to each other, partly by an attraction between the heat and the particles of which the body is composed, and partly by the radiating power of the heat. A greater or less density, or an aggregation of the parts of bodies, producing a considerable effect upon the conducting powers, would induce the supposition that the worst conductors should be regarded as merely the most effectual retarders of heat, and the best conductors as simply those that have the least power in retaining the heat that has been imparted to them. This view supposes the conducting of heat by bodies to be the radiation of it from particle to particle, operating at very small distances. Hence solids are better conductors than loose bodies, as the particles are more contiguous, and admit a more rapid communication of the subtle element. Those bodies that radiate heat best, imbibe it best; and those which radiate worst, imbibe worst.

The specific caloric in bodies suggests the relative quantity of heat, or the quantities that are necessary to produce a given change of temperature; the absolute quantity states the amount of temperature which the body possesses without any addition or subtraction. The specific heat has been supposed to be proportional to the absolute heat of bodies, and that the heat emitted or absorbed by a body, when it changes its state, is merely the consequence of the change which has taken place in its specific heat. Unfortunately the truth of the two suppositions upon which this ingenious reasoning is founded, cannot be admitted. There is no proof that the specific heat of bodies is proportional to their absolute heat. The second supposition is at variance with the mechanical phenomena which present themselves when substances change their state, and would leave that change itself unaccounted for. It cannot, therefore, be admitted, and the various methods must be rejected that have been proposed for the solution of this most important problem.

Caloric not only increases the bulk of bodies and changes their state, but its action either decomposes many compounds altogether into their elements, or it causes these elements to combine in a different manner. Combustion is an extension of the action of heat, and it banishes the properties of the bodies that undergo the process, and confers others which they did not before possess. When a body changes its form of existence, its capacity for heat is also changed. Liquefied solids and vaporized liquids have their capacities for heat increased, from being transformed into these conditions from their original existences. This change is effected by combining with caloric, or by separating from it, according to the absolute condition which the bodies enjoy.

Heat is to be regarded as a material agent of a peculiar nature, highly attenuated, and, from its affinity or attraction for all other matters, universally distributed amongst the particles of bodies, in quantities proportional to their mutual attraction, or, as it has been termed, the "capacities" of different substances for heat; whilst its tendency to diffuse itself amongst contiguous bodies has been explained on the supposition of its own particles being repellent of each other. Another opinion considers heat as a mere quality of matter, and ascribes it to a vibratory movement among the intimate particles of bodies; but the idea seems vague and unsatisfactory. There is no explanation of the manner in which this motion is produced, and no movement can be conceived without an impulse, nor an impulse without a material agent. Heat pervades all sorts of matter; it remains in some circumstances dormant, or, as it is termed, "latent," and may be again elicited from bodies by various means. Heat may be supposed to be produced not merely by the motions of the particles of the heated substances, but by the vibrations or undulations of a very subtile matter existing in all bodies. This will approximate the vibratory theory to the first-mentioned opinion, and also to the undulations that are explanatory of the phenomena of light, to which heat has so intimate a relation. The nicest balance fails to ascertain the accumulation of heat in any body, owing to the very extreme subtilty of its form; the fluidity is proved by the ease with which it insinuates itself amongst the particles of matter; its affinity for other matter is shown by its being universally contained in all bodies, in proportions differing in each kind of substance; its repulsion amongst its own particles is proved by its tendency to exist in a state of equilibrium in contiguous bodies.

The effects of heat are four in number:—1. Temperature, or the production of the sensation of heat. 2. Expansion, or the simple augmentation of the bulk of a body, without altering its condition. 3. A change in the physical state of a body, by which a solid is converted into a fluid, and a fluid into a gas. 4. Ignition, or the operation of heat by which a body is rendered luminous. Temperature is the effect produced by heat on the animal body, which will vary according to the quantity of heat which it contains, and may be said to be in the direct ratio of this quantity; although the indication of temperature, which is derived from the sensations, is much too vague to enable the laying down an exact scale of admeasurement. The proportion of effect only applies to the same body, or to those of a similar kind; for it has been found that the same quantity of heat affects the temperature of different bodies in very different degrees. These different effects depend partly upon the capacity of bodies for heat, and partly upon their conducting power, which points have been already discussed. Expansion arises from the distribution of heat among the particles of bodies, and remains so long as a high temperature is maintained; but when the heat is withdrawn, the body begins to contract, and by degrees it acquires its former bulk. This expansion occurs, with very few exceptions, in all bodies; but it differs extremely in degree. It is by much the greatest in aëriform fluids of all kinds. It is less in quantity, although still considerable, in liquids; while in solids it is so small as not to be perceived, except by the intervention of an apparatus expressly contrived to render it visible. Not only general classes of bodies, but individual substances comprised in the classes, have very different degrees of expansive power, which has been frequently made the subject of experiment. Ignition, or incandescence, is the property which bodies possess of becoming luminous, after being exposed to a high temperature, without any chemical change taking place in their composition. Combustion is an extension of ignition, by which the body extricates light, is consumed, and a complete change is effected in its chemical nature.

The third effect of heat is the most important, and appertains precisely to the present purpose. The effect of caloric consists in introducing a portion of heat between the particles of bodies, by which they are to a certain extent separated from each other, so as to experience an increase of bulk, without having their cohesion materially impaired. If, however, the addition of heat be continued beyond a certain limit, the particles are removed still farther from each other, until at length they are so far separated as to lose their cohesive power, and to become easily moveable among themselves in all directions. By this change of form, the substance in question undergoes a complete alteration in its physical properties, and not unfrequently in its chemical action on other bodies. The effect is produced by destroying the balance between the expansive power of heat and the force of attraction; the former tending to remove the particles of bodies to a distance from each other, the latter to retain them in close contact. But though the attractive power is conceived to be very much weakened in bodies that are so much separated in the particles, it is not entirely destroyed, but is still exerted with considerable energy.

These considerations allude to the fusion of solid bodies by an intensity of caloric, by which they become fluid, and to a further expansion by which the liquidity is evaporated into aëriform matters, and is transformed into gases from being volatilized by a larger introduction and use of heat. Every kind of matter has been with reasonable propriety supposed to possess the three forms of solid, liquid, and aëriform, and the different conditions of formation only infer a varied temperature under which they exist. The earths are not fusible by any known powers of agency, though the discovery may not be distant, as in some other similar cases. Limestone resists the utmost power of the furnace, which arises from the escape of the gas with which the homogeneous body is combined; but when it is confined by a severe compression, the fusion becomes quite easy. The earths may be infusible from a similar reason, or by the escape of the gaseous products that arise from the contact of the earthy body with the subtile element. But, though this part of the application be not attained, the sunderment of the mass is thoroughly effected, attended with a destruction of the power of cohesion, and the particles are disjoined, and never again adhere in an agglutinated form. This condition falls short of the state of fluidity, which exhibits the most complete change which nature admits; while the altered state of the earthy condition exhibits the particles in a different position, but still retaining the primitive nature divested of its peculiar properties, and endowed with new qualities which did not before enter into its composition. On this effect of heat, the following proposed alteration is sought to be established.

Clay being composed of a viscous clammy earth with sulphuric acid and water, presents an obstinate resistance to action of any kind, whether it be exerted for the external purpose of reducing the indurated texture, or in the mixture of earthy materials or fertilizing substances with the view of stimulating the efforts or improving the nature of the land. The acid is one of the oldest in the use of chemistry, and bore the names of "oil of vitriol" and "vitriolic acid," as it was obtained by distilling the salt called green vitriol or sulphate of iron. It is an acid product from the base of sulphur, having 150 proportions of oxygen combined with 100 of the base, being the largest quantity of oxygen in any acid except the boracic. The acid is liquid, of a somewhat oily consistence, transparent, and colourless as water, without any smell, and of a very strong acid taste. It destroys the texture of animal and vegetable substances. The specific gravity, when as strong as possible, is about 1·85, and the specific caloric 0·35. It changes all vegetable blues to red, except indigo. It boils at 546°; and when exposed to cold it crystallizes or congeals. It freezes at 45°, and the temperature necessarily depends upon the strength. When stronger or weaker, it requires a much greater degree of cold.

It has a strong attraction for water, and when exposed to the atmosphere, imbibes nearly seven times its weight of that liquid. When the two liquids are mixed together, a considerable heat is evolved. The strongest sulphuric acid of commerce contains about one-fifth of water, and the remaining four-fifths are pure acid. It is a compound of one atom of sulphur and three atoms of oxygen, and contains—

Oxygen	60
Sulphur	40
	100

Oxygen does not act upon it nor combine with it, and the acid is not altered by exposure to light or heat. Azote has no action on it; and when concentrated, it has little action on the metals: on gold and platinum it has no effect whatever. It unites readily with the alkalies, earths, and metallic oxides, and forms with them a class of bodies called sulphates.

Sulphuric acid is a most noxious ingredient in every case of contact with animal and vegetable life, and consequently must be expelled in order to render the earth a useful body for the purposes of cultivation. To drive off an acid from the salifiable base with which it is combined, the case of lime shows that a violent and continued heat is required, which, being strong and powerful, expels the acid in the form of a gas, and is much facilitated by the presence of vapour. The loose combination of the gas with the earthy base may allow this effect with comparative facility; for in the case of gypsum, or the sulphate of lime, the most violent heat is unable to expel the acid, and the earth remains unchanged. It is not known in what quantity, or in what ratio of combination, the acid is associated with the earthy base of clay; but it may be inferred from the cases of lime and gypsum, that very great violence will be required for the purpose of expelling the noxious ingredient. Quick-lime has been long known and used as a caustic solvent of much power, and as producing very beneficial effects in the ultimate results.

Lime is an alkaline earth in combination with carbonic acid gas in about—

Base	56
Acid	44
	100

The other ingredients are few and very minute. A very violent and continued heat expels the acid in the form of a gas, and the stones in lumps are seen as cinders, that are much reduced in weight, but no way diminished in size. When this condition of the rock or stone is supplied with moisture and the contact of air, a hissing noise takes place, a vapour arises, much heat is evolved, and the cinder falls down into a powder of very minute globular masses, exceeding the original bulk in the ratio of 2 or 3 to 1. This heat assumes the shape of damp exhalations rather than a fiery ignition; but light attends the evolvement in a dark place, and the confinement of it produces combustion. After lying a determinate time, the powdered earth imbibes a portion of carbonic acid gas from the air, of which it is a component part, and assumes the mild nature which it enjoyed before the banishment of the gas conferred upon it the caustic quality. But it does not again adhere or become solid, and remains in the condition of a mild earthy ingredient. Having undergone the action of fire, it has lost the former condition, and has acquired new qualities which it did not formerly possess. In the caustic condition it has been much used as a solvent in reducing the texture of fibrous bodies, and in changing the nature of harsh and repulsive materials. The compost manures got from the mixture of lime and earths show the power of hot unpowdered lime in reducing the texture and altering the nature of the most obdurate earthy materials; the earthy mass and the cinders of lime are mixed in an intimate contact; the contact of air through the cavities of the heap, and the moisture in the earths, dissolve the lime, when an enlargement of bulk takes place, much heat is evolved, which most thoroughly penetrates the mass, unbinds the texture, sunders the particles, and destroys or banishes every liquid adherence. Turnings or movements of the mixed heap provoke fresh motions of the elastic matters, till no more heat is evolved or enlargement happens, when every action ceases, and the quiet materials subside into a soft mucilaginous mass that has proceeded from the earthy bases of the opposite matters, which have been acted upon by contrary qualities and reciprocal affinities. This mass of mixed ingredients has been found to be a very rich application, and never fails in yielding the anticipated effects. Caloric or heat is one chief spring of chemical affinity; it dilates bodies, separates the particles, diminishes the attraction for each other, and proportionally augments the attraction of the particles of adjacent bodies, and consequently produces combinations and facilitates reciprocal unions.

The conversion of clay and of clayey substances into a very valuable manure, by being mixed with, and operated upon by, the caustic action of incinerated lime that is seeking to regain some part, if not the whole, of its primitive existence, leads to an extension of the practice in the application of lime to the clay lands of the fields, and to convert their wet and clammy constitution into dry and productive loamy grounds. This operation will be best performed by the lime cinders being dug into the land by the spade, after a complete summer fallowing and a thorough draining, which is imperatively required by reason of the very extreme solubility of lime in water, and its consequent inutility and total loss for any useful purpose. The depth of the digging may be one spit of the spade, or 9 in., and a good spadesman will dig an acre of ground in two weeks, or twelve working days. But as all clay lands are stiff and heavy to work, and some of the soils are most exceedingly waxy and obdurate, the space of three weeks may be given to dig an acre of land; and the placing of the lime shells in the trenches in the requisite quantity and position will occupy more time than if the land was only moved and carelessly thrown aside. This time of eighteen days of a man, at 2*s.* per day, is £1 16*s.*—the cost of digging the ground, and of placing the lime cinders in the quantity for mixture.

Judging from the mixing of clay and lime in the compost heap, it is assumed that one bushel of quick-lime will be sufficient for a cubic yard of ground; and the depth of nine inches will require 36 square feet, or four square yards, to constitute a cubic yard; and to form 1210 cubic yards, or as many surface plots of grounds as determined by the quantity of 4840 square yards in an acre, according to this calculation will require 1210 bushels of lime, which, at the average price of 6*d.* per bushel, will make the cost for lime to be £30 5*s.* per acre; and, added to the cost of digging in, £1 16*s.*, will form a total of £32 1*s.* A general average may be written at £30, to comprehend varied cases and modifications.

A timid and short-sighted inspection will, without any reflection, condemn the above plan—the cost being fully equal to the purchase of the land; and on that account it is wholly inadmissible into the list of things reasonable to be done by the cultivators of the soil. It is at once admitted that such operations are wholly removed beyond the sphere of the farmer; distant prospects are not within his calculations, nor suited to his means, and the permanent possessor must be saddled with performances that are intended to yield a benefit in future regularity. And, farther, very extensive and lasting objects of attention, such as the change of clay into loams, must become a national concern, and be done at the general cost of the people. The loans of money that are now granted by Government for draining wet lands must be extended in their purpose, and comprehend all objects of cultivable utility, such as that now detailed; the amount granted should be quintupled, the time for repayment doubled, and the charge of percentage cut into one-half. General utility always requires a varied comprehension for the development of the intention that is entertained.

But in all intended operations of any kind, degree, or extent, not the ways, means, or methods form the primary consideration, but the object that will be attained; not the present loss that will be sustained, but the ultimate results that will crown the efforts of the enterprise, and the fruition that will be obtained in a never-failing continuance. "Let us only find a thing," said D'Alembert, the celebrated French mathematician, "and there will be found plenty of persons to put it into shape." In like manner, let the ultimate result be shown of clay lands being mixed with lime, and the means will soon be found, economically regulated, and ungrudgingly and beneficially administered. When a result is fairly conceived "ideally," the realization of it is more than half attained.

When the land has been dug by the spade, and the lime cinders placed in the intervening trenches of the regular movements of the soil, the moisture in the clay lands, and the access of air through the interstitial cavity of the land that results from the digging, will dissolve the lime shells, the bulk will swell and heave the land, a large evolvement of heat will follow, the caloric will thoroughly penetrate the aluminous mass, unbind the texture, sunder the particles, and banish the sulphuric acid and water which form a part of the composition of the clay. In order that these objects may be fully accomplished, the quantity of force employed must be able to overcome the resistance, and so completely to expel it as never again to appear in kind or degree. The quantity of lime must preponderate, and completely overpower the nature of the clay; the quickness and violence of the agent must be supported by power, which consists in quantity, or the amount of the force that is being exerted. On this principle the whole application rests in its value and utility; for if the clay be more powerful than the lime, the latter body will quickly cease to act, will produce no impression, and sink into utter insignificance. This failure attends many enterprises, and comes from a scanty allowance of means, whereby the resistance is not quashed, and no object is attained. When a result is wished from any enterprise, the power must be overwhelming to the resistance that is opposed; any defence is immediately defeated, and so completely prostrated as never again to appear in any shape of resistance or opposition. If the expelled qualities of clay again return, the object is only half attained; a repetition of the process becomes necessary, and a never-ceasing expense is incurred; whereas a complete performance attains the object, and requires not any repetition. It is not here asserted that one bushel of lime to the cubic yard of ground will in every case thoroughly effect the desired purpose of completely altering the composition of clay lands; but the statement is made as an analogical probability. The plastic and London clays may require more, and a less quantity may suffice for the clays of a weaker texture. Trials must decide.

The force of the heat will expel the sulphuric acid, which will escape as vapour, and it will not be again imbibed by the clay, as it does not form any component part of the atmosphere, as in the case of lime being again supplied with carbonic acid gas from the air, in which it exists as a portion of it. In this case, one act of expulsion serves the purpose for ever, and no future presence demands a repetition. In the other part of the performance, the spongy porousness of the aluminous earth is thoroughly broken up and sundered by the disruptive agency of the caloric, and so thoroughly dismembered as never again to adhere and form any ductile plasticity, which is the grand characteristic of the family of clays. When the action of lime has ceased by reason of the heat being all evolved, the quiet subsidence is a mucilaginous mass of earthy materials, which is easily decomposable, and fit to be used as a soil for growing any crops that may be planted. The texture of the lime has been disrupted and powdered, the clay has been divested of its hurtful quality and noxious ingredients, and the two new formations become amalgamated, and enjoy qualities that are wholly new, and altogether alien to the former existence. In changing condition bodies also change capacity, or the power of receiving and retaining heat, by which they are raised to a higher temperature by a quantity of caloric that bears a certain ratio to the amount necessary to heat other bodies of a like formation and consistence. Heat is both a cause and effect of the change of bodies; it produces the alteration, and is produced by the change, and is well known to be a very powerful means both in forming combinations and in separating substances that have been joined by affinity. The atoms or ultimate particles of bodies unite chemically; the large masses only touch in the surfaces, and have no action on each other. Hence all bodies that are intended to be combined must be fused, or reduced to particles; and hence the use of the solvent power of heat evolved by the lime in penetrating and sundering the viscous mass of clay. When bodies unite chemically, the union is always accompanied by a change of temperature; sometimes the temperature sinks, but in by far the greater number of cases it rises. Alumina, or the basic earth of clay, has a strong affinity for lime, and easily melts with it when it exceeds the lime in quantity; but when the lime exceeds, fusion does not take place. This affinity expels the sulphuric acid from the clay with which the lime combines, as it is a homogeneous body, and tends to form unions with most bodies in contact. The clay is mollified, and the lime is slaked by the surrounding moisture, and a product is effected that has little or no resemblance, as water would not be supposed to proceed from the union of two gases, or oxygen and hydrogen.

When bodies are united chemically with each other, the separation cannot be effected by filtration, or any mechanical means whatever. Heat enables a separation, and must be applied in quantity as directed by the volatility of the substances that are united. Sulphuric acid does not boil till heated to nearly 600°, while water boils at 212°; and as volatilization does not proceed but from above the boiling point, the heat must be able to produce that condition in the liquid substance. Hence the quantity of lime must be large that is applied to the alteration of clay lands, in order that the force of the heat may volatilize and expel the acid which is contained in the soil.

Affinity is the unknown force which causes the ultimate particles of different bodies to unite together and to remain united. Decomposition is the measure of the strength of affinity, and destruction proceeds from the attraction of certain bodies wholly overpowering the existence of inferior powers, and which are expelled or altogether destroyed. The superiority of the attraction of alumina for lime will overpower the adhesion of the acid, which will be raised by the heat to the state of vapour, and fly off without appearing again, or it is decomposed and wholly destroyed. The water is combined with the lime and solidified; hence the heat evolved, and the reduction of the lime to a fine powder. Bodies combine from being in different electrical states, or in being positive and negative; but to what circumstances these conditions are owing cannot be explained. If these electricities constitute two distinct fluids, the surfaces of the bodies may be coated with a quantity of the respective qualities, and, from the well-known phenomena of electricity, it can scarcely be doubted that the electricities are not inseparably attached, but capable of being increased or diminished according to the laws which bodies follow with regard to electricity. Hence it happens that a substance may be in one electrical state when compared with one body, and in another electrical state when compared with another. Thus oxygen has a great preponderance of negative electricity; it is negative with respect to every other body. Sulphur is negative with regard to most bodies, but it is obviously not so powerfully negative as oxygen. The investigation of this theory is most difficult, and the results are not very conclusive. At all events, practical applications of substances cannot be directed by the discovery.

The new earthy formation that will result from the mixture of clay and lime will enjoy the advantages of a higher temperature, an improved capacity, a mollified nature, and a sweetened constitution, which always follows the action of lime and of all calcareous matters. The increase of temperature is an acquisition that is not exceeded in value by any benefit that can be conferred upon land in the shape of improvement, as it promotes the action of manures, and advances the health, vigour, and maturity of plants. The coldness of clay lands, which is induced by the superabundance of moisture, forms the quality that sinks their value and utility; the cultivation is retarded, and the maturity is delayed of every crop that grows upon the ground. The excess of moisture must be removed by draining, and the retentive quality must be abolished by a violent dismemberment of the viscous texture, and so completely performed as never again to assume the original formation. This purpose being effected, an increase in temperature will follow, both from the calorific quality of the lime, and from the constant attendance of that property upon every change of the condition of bodies. A very reasonable opinion may be entertained that the benefit of lime, in any shape or form, consists in its conferring a higher temperature to the land by means of the caloric which it holds, both from its own natural constitution and from the phlogiston of the fuel by which the gas was banished and the texture unbound. Clay lands have never been in any way benefited by scanty applications of lime upon the surface, as clay is a bad conductor of heat, and the quantities of lime that are used are much too small to overcome the repulsive quality of the earth. The exuvial matters are deficient in the quantity necessary to imbibe and retain the caloric, which is itself wanting in the requisite amount to produce a desirable effect. No beneficial change can be made in lands without conferring an increase of temperature; a cold inert application of any kind will only add to the dormant mass, and increase the difficulty of future beneficial actions. An agent of quick force and obstinate energy must be employed, which both uses and engenders the quality that is sought, and which remains for permanent utility. Temperature, or more generally the climate, produces all the vast variety of differences that are seen to exist in the animal and vegetable worlds, and it rules with the same influence in the sources of production as on the formations and tempers of organized substances.

Capacity of bodies signifies the proportional capability of a given quantity of any substance to absorb and retain caloric, or that disposition or property by which various bodies respectively require more or less of this fluid to superinduce any given temperature in a given mass. It has been long known that this capacity varies in different bodies, and that among substances the same body in different states of existence presents equal varieties in its capacity. A change in this respect is producible in three ways—by mechanical compression or dilatation, by chemical combination, or by the action of heat itself. It is a general fact that when a body is enlarged or dilated in its bulk, its capacity is proportionally increased, and when its bulk is diminished, its property is lessened. The capacities of all bodies are increased in some proportion by the disintegration of their constituent parts, as well by the agency of caloric as by any other cause. This case of change of capacity by the action of heat itself is perhaps productive of more important effects in nature than either of the other two. By it the quantities of caloric and of cold are alternately absorbed and emitted which regulate the heats and colds which hold the universe in an equilibrium; without it, all boiling water would be dissipated in explosion, and the polar ices would be dissolved in a heat above 32° if the thaw was not regulated by a degree of cold that proceeds from the caloric that is absorbed by each particle in its solution. The capacity or property of any body to absorb and retain caloric confers upon it the degree of temperature which it enjoys, and this has been shown to exercise a great and lasting influence.

The nature of clay lands is qualified in the harshness by the mixing with lime; the viscous clamminess is relaxed, and the temper is rendered gentle and tranquil, pliant and supple. The watery sourness of the soil arises from the quantity of sulphuric acid in union with water, and though the acid be not in excess, so as to produce a very sensible acidulousness, yet the effect is yielded of a noxious acerbity which is detrimental to every kind of life. Both the acid and the water in union with it are completely dissipated by the searching penetration and energetic force of the caloric emitted by the dissolution of the cinders of lime; the texture of the whole mass is so thoroughly disintegrated and reduced, that no part remains untouched, nor any corner unexplored. Not only volatile bodies, as acids and water, yield to its influence, but earths and earthy aggregates are sundered, though not fused, and transformed, though not liquefied. And the alteration is permanent, as the affinity is destroyed for the presence of the noxious inhabitants, which do not again return, but give place to more harmless and beneficial elements, which are induced and brought forward by the new constitution of the soil.

Lime is a calx or residual substance, and, along with all calcareous bodies, inherits the property of expelling sourness and acidity of every kind, and of introducing a sweetness that is agreeable both to the taste and smell. The surface grasses of sour pasture grounds are improved by a quantity of lime being spread over the land; the coarse herbage is removed, and more grateful plants are brought into use. The earth of clay being divested of the noxious volatile ingredients would remain meagre and inert, and become a mass of dormant particles without cohesion or tendency to combination. But the presence of lime presents an appearance of wholly new features; and during the violent disturbances that were effected by the agency of the caloric, not only a mechanical mixture may have happened, but a chemical combination may have been consummated. A mechanical mixture is the general limit of the efforts of man, and leads to the chemical union; it affords the ready path to the action of reciprocal affinities, which, without its aid, would have no opportunity of exerting their mutual influence. The whole art and use of chemistry consists in forming compounds by uniting different bodies with each other; and the best and most skilful adaptation comprehends the knowledge of the auxiliary substances that will effect the decomposition of the body that is the subject of operation, and form the newly-united mass of a more benign and useful disposition. For this purpose lime has been selected, as it affords the powerful agent of caloric to penetrate and crumble the earthy mass, has a sweetening residual quality, and confers, from its constitution, a very large capacity for the purposes of caloric, than which quality no higher recommendation can be attached to any body.

A loamy soil of the richest kind will be formed by the mixture of clay lands with lime, as the aluminous earth affords a strong and durable base for the constitution of the soil. Clay is the chief element in the composition of all rich lands; it imbibes and retains the necessary moisture, and the presence and action of the other ingredients prevent the hurtful excess, husbands the use, and regulates the expenditure. Calcareous matter is also an essential ingredient in soils, and it will be supplied by the lime that is used to effect the new formation. A clayey loam will be produced that is the most productive of all soils, as it grows green crops and wheat, which are highest in value of all the plants of the farm. These soils could not yield the value without a large proportion of clay in the elemental composition, which is formed into the rich condition by the presence and introduction of the other ingredients, as sand and the exuvial matters of organization. Clay and lime in mixture tend to form an artificial marl, of which natural body the fertility is well known. The nearest approaches to it are made in the way now recommended.

The expense of changing all clay lands into loamy soils of the most productive kinds has been averaged at £30 per acre; and it has been mentioned that the ultimate object must form the primary consideration, and not the ways and means of doing the action that is proposed. If the latter were allowed to overrule the deliberation on any project, no enterprise of any importance or worth would ever be commenced or consummated: the frigid calculations of self-interest must be excluded, and the niggardly economy of expected reimbursement. The project must be placed on the broad pedestal of national benefit, and reared into perfection by the application of general resources. The performance must not rest upon the opinions of reference or the answers of ignorance, nor condemned by the jealousy of conceit or the dread of innovation. Such beneficial purposes are too often upset by prejudice and overturned by clamour, and very frequently in direct opposition to the evident and acknowledged advantages that would accrue even to the quarter whence the blinded unwillingness has its source. Such an expense must be borne by the national funds, and the repayment made by a fixed yearly percentage paid from the land, and of such an amount as will effect the liquidation in a reasonable period of time, and without disturbing or impeding the current of action that must be followed after the change of the lands has been effected. The ground will now produce all kinds of green crops in the highest perfection, and the manufacture of these products requires farm buildings of a large extent and a peculiar formation. These appurtenances must be adequately supplied from the same source, or the full value of the changed grounds will not be obtained. The conversion of any products into use is deserving equal attention with the raising of them; the finest articles and the most valuable materials may be wholly spoiled in the process of manufacture, and the greater part of former labour altogether lost. A change of the produced articles demands an altered manufacture, and the conversion proceeds upon wholly different grounds and a varied application. The larger bulk of a heterogeneous produce will require more outlay in the conversion, and this latter purpose will demand a greater extent of application. These consequences will follow the change that has been proposed.

Loamy lands are in the general average at least three times the value of clay lands, except a few cases of the rare quality of the first order. The clays of the shale and of the marine tertiary formations will constitute soils of the highest power of loams, as the staple is deep and abundant, and the elemental constitution of the earth is strong and durable. Hence the value of the new soil may be assumed to be four times that of the clayey condition, which is generally poor, except in some few localities that enjoy abundance of manure from large towns. The improvement will consequently increase the yearly value by not much, if anything, less than 30*s*., or, upon safe grounds, from 20*s*. to 30*s*. per acre. This sum will pay the cost of alteration at some time within twenty to thirty years, a period of time that is not at all outrageous, when due allowance is made for the vast and incalculable benefits of the application. Four times the value of land must be understood to mean four times the quantity of produce from the surface, which will form a very large addition to the supply of the necessaries of life, and tend to cheapen the value of articles of consumption, as well as enlarge the sphere of their use, which is the just aim and legitimate end of every scheme that adapts the earth to its purposes. The resources of the earth have never yet been half developed, by reason of sufficient means not having been applied to its cultivation. Skill and labour exist in the most ample abundance; but the other moving power is ever wanting, from penury, unwillingness, a niggardly economy, want of security, and, worst of all, from the absence of any proper social regulation to meet the exigent demands of the very peculiar necessity that most imperatively exists. Land, being made an individual possession and a private speculation, never can obtain the just consideration, nor answer the objects of its purpose.

Every purpose is a subject of legislation that has for its object the well-being of man, and for which reason can assign just grounds. Of all intents that can be entertained by the mind of man, or enter into any human consideration, no single one nor any number of them are any way to be compared with the employment of labour, and the adequate supply of the necessaries of life for the use of the population of any kingdom or country. The natural wants must be supplied before the moral—the cravings of nature admit no excuse. The structure of social and political theories serves only to show the sandiness of the foundation and the unskilfulness of the architect; the framing of commercial codes and artificial regulations merely discover the ignorance of the compilers ; time and circumstances overturn all such baseless fabrics; but practical performances that are done on an enlarged scale of comprehensive benefits withstand all changes, and never desert the prestige of their just reputation. No government can bestow on its subjects—no legislative enactments can confer on the human race—no class of men have in their power to give to another class, benefits any way comparable with the comforts and blessings that arise from an adequacy of food and raiment, in order to uphold the body and furnish the means of mental development. No state policy can exist unless it be based upon this indispensable foundation; broils, tumults, and discontent will constantly assail it; it bears on its front the stamp of imperfection, and without the above primary provision, all systems of education are contemptible and wholly impotent. The extremities of the body receive the impressions, and while the feet are bare and the head uncovered, the emanations of the mind must be miserably deficient, if not wholly wanting. Most writers on this subject either do not know or overlook the ground on which the whole matter rests; they neglect the foundation in the haste to rear the superstructure. Individual interests have ever been preferred to the general good; and a great misfortune consists in those persons who have power being usually an entire generation behind those who are less employed and less conceited. Power being joined with means is capable of converting sterility into fruitfulness, and a wilderness into productive ground; it can supply the defects of nature by drawing from the storehouse of its bounties; it can fructify the energies of mind and the toils of labour; it can raise human society from the depths of moral depravity to the heights of intellectual grandeur, and convert its most virulent passions into the most healing and nutritious juices. Those persons who write about man and the different states and stages of his existence, political, moral, and social, would do well to remember two things—the cultivation of the earth, and the supply of the necessaries of life, for they uphold or overturn all their ideal fabrics.

CHAPTER VII.

Derivation and Meaning of the Term Loamy Soils.—Natural and Chemical Qualities of the Substance.—Origin and Geological Position of Loams.

THE term "loam" comes from the Saxon word "lim" and "laam," the German "leime," the Latin "limus," from the Greek "λιμνη," meaning a fen, all the words signifying a fat, unctuous, tenacious earth. Under the name of loam there is comprehended a class of compound or mixed earths, composed of dissimilar particles, hard, stiff, dense, harsh, and rough to the touch, not easily ductile while moist, readily diffusible in water, and usually composed of sand and tough viscid clay. All the terms having reference to a viscid agglutination, the obvious meaning shows that clay must be understood as a very considerable part of the composition of loam, as it imparts the ductility in a greater or less degree to any substance with which it is mixed. Every mention of the word implies a puddled earth with which to smear or close any opening or aperture that might occur; and for this purpose the plasticity must be conferred by the earth of clay that was in the mixture.

Hill comprehends under the class of loams two genera:—1, the Thraustomicthes; and 2, the Glischromicthes. The first are composed of sand and a less viscid clay, and are of a friable and crumbling nature. The second are composed of sand and a more viscid clay, and are of a more rough and viscid texture.

Du Costa distinguishes them by their colour—into black and white, which are not acted upon by acids; yellow loams, some of which are not acted upon by acids; and other alkaline, brown loams, some acted upon by acids, to which class belongs the Windsor loam, so well known and so much used for making bricks, and building furnaces; others alkaline; and the green loams, not acted upon by acids, and suffering no disturbance.

According to Woodward, loam consists of clay mixed with fine sand, or of clay with a superabundance of sand; and Mr. Bergman, having analyzed some loam found in the neighbourhood of London, and considered to be very excellent, found it to consist of 87 per cent. of a reddish gray sand, as fine as meal, and 13 of argil. Supposing, therefore, clay to consist, as it most generally does, of 30 per cent. of argil and 70 of fine sand, it is found that loam of the best kind contains an excess of sand amounting to 17 per cent.; if the excess of sand be greater, it will form what is called a sandy loam; if smaller, a clayey loam. Mr. Bergman found nothing calcareous in the loam. When it contains any, it so far inclines to the nature of marl, and this marlaceous loam may be either sandy or clayey, according as the proportion above indicated is exceeded on either side. But loams most frequently contain a portion of the calx of iron, which is more or less oxygenated, a circumstance which produces a considerable variety in the colour, and very probably also in the vegetative powers of the loamy earth; if its proportion be considerable, viz., four or five per cent., they often also contain some proportion of the vitriolic acid. The colour of loam frequently proceeds from that of the calces of iron contained in it, but more frequently from its sandy part. When gravels and pebbles are mixed with loams, the distinctions arise of "gravelly, stony, siliceous, and limestone loams," according as these substances predominate.

Loams are generally understood to consist of clay, siliceous sand, and the carbonate of lime. The quantity of iron, magnesia, and various salts, is so inconsiderable as never to alter materially the texture of the loam. Decayed vegetable and animal matters in the form of mould, or "humus," are often found in loams in very considerable quantities, and the soil is fertile in proportion. Loams vary in quality, according as they are composed: those formed of loose sand, with little humus, and with an impregnation of iron, are very unproductive; and those which contain too much clay, and lie upon an impervious subsoil, are very difficult to cultivate. The pure earths are in themselves almost entirely barren. Sands receive and discharge moisture much too quickly; clays retain it too long in its own substance, refuse it when wanted, and starve the roots of plants in a cold impervious mass; chalk has the same mechanical quality, and contains very little organic and soluble matter. Sand and clay alone would not make a rich soil; but a portion of calcareous matter and humus being added, the mass is rendered open and porous, and the clay and sand are prevented from forming a mortar, which hardens readily and prevents the influence of the air from reaching the roots. Loams and all fertile lands contain some portion of calcareous earth, and sand will be less necessary as humus abounds.

The most general acceptation understands loam to have proceeded from the viscous slime that is formed in the beds of ponds and rivers, and in the streamlets of water which, in the form of torrents, sweep the loose earth from the surface of the roads, and deposit the sediment in the quiet places of recess. This formation exhibits a very minute reduction of the particles of the different earths, and an extreme comminution of the substances, attended with a viscous adherence of the whole mass, arising from the nature of some of the materials, or from the very mixed qualities and properties of the different substances that are in contact. A stretch of inquiry fetches the meaning from a Greek word signifying a waxy humour of the eyes, which conglutinated and nearly shut the eyelids, and was extended to the pitch, or lute, or clammy substance of any kind which was prepared for the purpose of smearing wounds and stopping orifices. In this mixture, the variety of the ingredients always formed the chief distinction, along with the very minute comminution and intimate mingling of the materials, arising from the rolling action of water and the disintegrating capability of the terrene matters which undergo the process of suspension. Mud arises from similar processes, but the texture is weak and feeble, which proceeds from the non-cohesion of the particles that have been too distantly removed by the abundant action of the waters. Loam seems to be produced by a shorter process, which, having reduced the particles to a certain degree, leaves the power of cohesion sufficient to aggregate the mass in a very useful reciprocity. The texture of loam is fine, but not feeble; there are grades and degrees of it as of all other materials, but every variety possesses the adhesion that is necessary to promote a reciprocal affinity, and also allow the action of extraneous introductions. An adhesive clamminess has, in every acceptation of the word, been attached to loam, which does not adhere to substances that have undergone the ultimate processes of separation. Comminuted earthy materials of any kind have been called loams; but some very important considerations are to be taken into account before the general appellation be universally admitted. The peculiar elements must be present both in kind and quantity, in order to form the adhesiveness of particle that constitutes a primary quality, and at the same time admit the easy working of the earthy deposit of comminuted materials. These two accompaniments constitute the distinguishing characteristics of loam, and to them the retrospect must always be directed in order to view aright, and conformably treat, the earthy aggregation. And it is not the mere presence of elements that forms the valuable quality of loam, but the relative quantity of the ingredients, and the mode or manner in which they are blended or commingled to promote the reciprocal action of adhesion. The number of the elements is also very material, for combination is often effected by quantity, which becomes equal to a superior affinity of the single elements that are in contact. The reciprocal action is raised by the addition of more substances, which not only exert a direct influence on the materials which they touch, but provoke the mutual action of the ingredients that are already present. And the greater the variety of elements, the greater influence will be exerted.

From the original meaning of loam in a dense, harsh, gritty substance, adhesive and partially ductile, the name has been extended to all finely-reduced earthy formations that are loose in the texture and dissevered in the particles. In many cases the ductility is wholly absent, and, after being squeezed by the hand, the mass crumbles into a dry and loose incoherency. These bodies are most properly denominated loamy earths, as possessing the constitutional fineness of loams, but wanting in the density and clammy adhesion from the presence of clay. In this way the primitive term has lost much of the original meaning; the most apparent quality has been seized for use, while the equally important properties have been neglected, because they are not fully tangible to a careless observation. The presence of calcareous matter is also essential to the constitution of a true loam, as it imparts the grittiness of touch which arises from the residual particles, and also the softness that accompanies the pulverization of limestone. The oxide of iron is useful in communicating a hardened rigidity that attends the presence of metals. The mingling of the various substances confers the same character more than the materials that are present.

The quantity of "humus" in loam very much affects the nature and alters the quality. The literal meaning of the Latin word "humus" is "earth," or, more modernly, "mould." It is classed in mineralogy as a genus of the order of calcareous earth—its generic characters consisting of carbonate of lime, with a small proportion of silex, hydrogen and carbonic acid gas, and oxide of iron; formed by the decayed remains of animal and vegetable substances; light, friable, imbibing, but not retaining, water; meagre, rough, humid, of a dull colour; effervescing with nitric acid; becoming cinereous in a smaller heat, in a stronger, running into a frothy kind of glass.

"Animal mould" is impalpable, greedily imbibing water, hardly effervescing with nitric acid in its rude state, but sensibly so when burnt; white, or cinereous, very light, and fertile.

"Vegetable mould" is brown, in a very subtile dust, so very fine as to pass, when mixed with water, through a coarse cloth, or filtering paper. It affords the best and richest garden moulds, and is often black when moistened, and cinereous when dry. Decayed vegetable matters afford a most excellent soil.

Animal and vegetable moulds being mixed by their elements living and decaying on the surface of the earth, form the "humus" of modern scientific agriculture, a natural manure produced by the slow decay of animal and vegetable matters. "Humus" is a dark, unctuous, friable substance, nearly uniform in its appearance. It is a compound of oxygen, hydrogen, carbon, and nitrogen, which, with the exception of nitrogen, are the elements of all animal and vegetable substances. It is the result of slow decomposition of organic matters in the earth, and cannot be compounded chemically. It is the product and the source of living matter. The greater the number of living creatures, the more humus is formed; and the more humus, the greater is the supply of nourishment to life. Every organic being adds to the quantity of humus, which increases as men, animals, and plants increase upon the earth. It is diminished by the process of vegetation, and wasted by being carried away by water; or it is carried into the air by the agency of oxygen, which converts it into gaseous matter.

Humus, in the common state, is not soluble in water, and it is antiseptic. It is indecomposable in itself, and also in other substances in contact with it. It remains in the earth long unimpaired; but so soon as it is brought to the surface by the process of cultivation, an action immediately begins. The carbon of the humus unites with the oxygen of the atmosphere, and forms carbonic acid, which the plants absorb; the hydrogen, by the same affinity, forms water, and this moisture, being formed gradually, becomes a most valuable source of life to plants during dry seasons, when rains and dews are deficient. Soluble extract is the residue, which is taken up by the roots of plants. By the repeated actions of cultivation a further progress of reciprocal unions is produced, which afford a regular supply of food to plants; and from this fact we learn the great value of frequently stirring the ground in the culture of green crops.

Humus renders clay soils porous, consolidates loose sand, and suffers very much from stagnant water—the substance is rendered acid and astringent, as in peat, the vegetable matters become "sour," and produce rushes and other unpalatable and useless plants. In such cases the land must be dried by draining, and the acid neutralized by large applications of lime. In light soils very little humus is found, the air penetrates too freely, and speedily decomposes it, and the extract is carried downwards by the waters that pass through the soil. Such soils require to be consolidated by clays and marls to make them retain moisture. Humus acts most fruitfully with calcareous soils, provided they are deep and well pulverized.

Good lands contain, on an average, about four or five per cent. of humus, and two per cent. will render a soil tolerably productive. Humus being the production of animal and vegetable matters combined, it is yielded in abundance by farm-yard dung, which consists of the straws of the cereal crops, joined with the solid and urinary fæces of animals. And it is to this quality that the dung of the farm-yard is indebted for its superiority to any other manure yet known—that after the more active animal substances have exerted their action and have disappeared, there remains in the soil a residual mass for future decomposition, and which continues to afford for years the pabulum of organic life.

Loams being formed by nature of the mixtures of the primitive ingredients that have been now mentioned, partake very largely of the capricious diversity that is everywhere to be observed in the productions of unknown agency; the position is very varied, and the quality seems to be regulated by no definite rule that observation has yet been able to trace. The tops of moderately high grounds very often contain a greater depth of loam than the adjoining valleys, and the quality is also much more valuable. The most stubborn clays are often found on low grounds, and are comparatively unproductive, while the adjoining heights are crowned by a loam of more than medium fertility. The quality of the substratum has a very evident effect in conferring a value upon loams; if it be rocky, the loam is usually too dry and incoherent; if clayey, the loam will be wet and ungenial; if sandy, it will be too open and porous; and if gravelly, it will be liable to be scorched. The most fruitful loams are found incumbent on a bottom of clayey sand, or a compact gravel, joined and mingled together in such a manner that it receives the moisture downwards, and does not starve the upper soil, and at the same time keeps the moisture in store, to be given out as the upper soil may require it. A gravel cemented by clay, and made porous by sand, is, of all other substrata, the best adapted for the purpose now mentioned. A yellow and compact unctuous clay of a dry nature often supports a loam of the first-rate quality.

Humus appears to be most certainly distributed by the quality of the soil, land, or ground on which the animals and vegetables best like to live. All organic beings have the instinctive faculty of choosing and rejecting, and accordingly the greatest abundance of humus is always found on strata which experience has found to be most favourable to organic life. And the original deposits that are constitutionally inimical to the living organs of the creation are left devoid of any useful quantity of that essential element of fertility, and require to be supplied with it by artificial means. Humus is therefore produced by some natural productive quality that favours the generation of living organism, and it affords, in return, the elements of life to subsequent reproductions. The earthy vegetable matter, being the residuum of the decomposition of organized bodies, is a principal material in soils; it constitutes the layer in which plants grow, and differs greatly according to the quantity and quality of the matter itself, the state of reduction it has attained, and the manner in which it happens to be incorporated with the constituents of the soil. It has much influence on soils, in altering, modifying, and mixing the original substances of their composition. The depth of it determines the fertility of lands.

Authors are more at variance as to the components of humus, than as to its character; nitrogen is not indispensably present where ammonia has been entirely removed. An organic product called "humic acid" has been put forward as the chief ingredient of humus, and is found to consist of water and carbon only. It abounds in peats, old wood earth, heath mould, and in all decayed vegetable remains. It combines with alkalies, and forms "humates," which are dropped in brown flocks on the introduction of muriatic acid. These flocks, or the deposited humic acid, are little, if at all, soluble in water; and if they become the food of plants, it must be by very slow degrees and in extremely small quantities. According to this theory, humus requires to be treated with an alkali in order to be fitted for the purpose of fructification. Lime exerts its predominant affinity, and acts curatively on inert vegetable matter by removing the grand cause of barrenness. But sourness does not always indicate the presence of an acid; sand has no sour taste, and yet combines with soda and forms glass. The theory of humic acid must rest till further observation reject or advance the speculations on the subject.

The geognostic situation of loam is found overlying the diluvial detritus as a fresh-water formation, but most frequently it is a deposit on the vast accumulation of alluvial beds which, in very discordant and heterogenous mixtures, constitute the foundation of the greater part of the cultivated surface of the earth. The interposition is almost constant of a bed of aggregated earths between the subjacent rocks and the cultivable stratum of ground, and the qualities very often show an origin that is evidently different from any of the adjacent materials. The substances must have been imported in a reduced state, or have been mixed beyond recognition. The alluvial formation comprehends, in the most extensive meaning of the term, all the deposits above the chalk, or at least all those above the diluvial detritus, as the latter is most clearly seen in the gravels and erratic boulder drift. It is more particularly applied to the uppermost stratum, which forms the land of cultivation, and is now very appropriately designated the subaërial deposit. The formation of it by fresh water is universally allowed, as it contains no shells or fossils of any kind, and it shows a state of reduction that must have undergone an extensive and long-continued operation of a very powerful influence.

In the agricultural sense, loam is understood to comprehend every soil of earthy matters that are so minutely reduced as to permit the cultivation and growth of green crops. This range of extent pervades every corner of the kingdom, and there are few places where some sort of resemblance does not warrant the general acceptation of the term. Finely-reduced earths almost everywhere abound, and where they fail to form an entire soil, they exert very much influence in producing the constitutional character of the lands with which they are mixed. The term "earthy loams" will very correctly represent the general appearance and quality of the lands, which are further divided by the properties they separately possess. These inheritances are partly original and partly adventitious, and have arisen probably more from local peculiarities than from the primary source of formation. A very wide deviation is introduced from the original meaning, which must have in loam a waxy ductility that enables it to stick and adhere, and a gritty harsh feel which imparts the essential character. These true types very seldom accompany each other; but the presence of one or both in some degree constitutes the relative value of loam.

From the primary rocks which form the floor of the terraqueous globe, an increasing softness of structure attends each succeeding formation in the ascending series, and the stratification ceases with the chalk, which is a feebly aggregated mass of the carbonate of lime. The pulverulence of the matters above the chalk continues gradually to increase, and terminates in the uppermost layer of alluvium, which no doubt owes much of the reduction of texture to the contact of atmospheric influence, and to the processes of cultivation, which operate through the action of implements and manures, and by the agency of the roots of plants. The loose formations above the chalk are characterised by an extravagance of arrangement and deposition that is not exceeded by the subjacent location of rocks, which have excited the wonder and called forth the admiration of every rational inquirer. There are seen clays, sands, gravels, and earths, placed separately and in mixture, without any regularity or tendency to order; clays on high grounds, gravels on declivities, and light earths in valleys, and all in seeming discordance with the acknowledged rules of specific gravity. Allowing the clays and gravels to have been located by a higher flood of waters than has produced the uppermost alluvium, the fact of the best loams being often found on high grounds, and clays in the valleys, goes far to support the opinion that loam has been produced at different times and by different agencies, and that the foregoing large inundations had begun the process and the location, and the succeeding overflowings of water on a minor scale had finished the peculiar species of deposition. Loams on high grounds have been improved by subsequent exposure and cultivation, and in low situations the succeeding agencies of formations have effected the difference.

In many cases a very evident and direct similarity can be traced between the subaërial deposit, the alluvial bed, and the subjacent rock. On the sandstone rock the bed is a hardened aggregation of the rocky particles with an earthy mixture, and the upper stratum is a pulverulent portion of the bed that has been affected by external causes. The presence of "humus" very much alters both the appearance and quality, and the exposure to the air by frequent turnings of the soil by the tools of cultivation, has imparted a texture that is very different from the underlying materials. Dry compact clays in vast beds of hardened alluvium, or of diluvial aggregations, support a loamy stratum that has been converted into that name by the causes above mentioned—of humus and exposure—but which still retains so much of the clayey nature as to give the specific name to the cultivated land. These loams constitute the first-rate quality, as the texture has strength for the production of wheat, and the friability admits the fullest enjoyment of green crops. This pre-eminent property confers the highest value on the soils of the dry beds of clay. A stratum of gravel that is cemented in a bed of earthy clay or concreted alluvium, is, of all subsoils, the most favourable supporter of a fertile loam, for the porousness receives the water downwards, the upper soil is not starved by a superabundance of moisture, and the retentiveness is sufficient to hold the necessary quantity for the use of the growing plants in the season of drought. These mixed beds of gravel are the production of the fresh-water inundations subsequent to the diluvial formations, from which a part of the material is derived; or they may have been derived from the lattermost operations of the universal fresh-water deluge which by the almost universal consent of opinion has ravaged the globe. Any succeeding operations may have been comparatively partial, and have only effected some trivial changes on the already deposited accumulations. The highest ranges of chalk hills support a loose earth which relates immediately to the rock, being of a white colour, loose and feeble, dry and porous. It enjoys a small portion of humus, as the constitution of the rock is not enticing to the existence of animal and vegetable life, from which the exuvial matter proceeds. Hence the inferior quality of the chalky loams.

The simultaneity of the formation of loams and all fine alluvial earths may be inferred from the position of the relative deposits, which occupy heights, declivities, and valleys, without any irregularity or tendency to superimposition. The whole operations must have proceeded from a quiet action, and an orderly system of causes; the deposits are flat and even, and never deviate into any other form or inclination. They denote a settled and tranquil state of the earth, wholly divested of any agitation or turbulence, that has so very evidently disturbed and confused all the preceding deposits of the terraqueous globe. Still the formations are partially irregular, as the depth is least where the greatest might be expected, and a depth prevails where natural appearances would indicate a shallow deposit. This consequence may have arisen from the longer or shorter movement of the waters, and to the abrasion of the subjacent materials being easy or difficult. Hard rocks resisted the decomposing agent, and the alluvial stratum is shallow; softer rocks yielded to the power, and the stratum is deeper; while alluvial beds have afforded both, the upper and under soils differing in consequence of the situation and exposure. The flat and heavy surface of clays resisted the impression of water, and the fine earth was not produced; but sand and gravel received the operations and yielded the lands that have been described. But it must be acknowledged that many situations exhibit the introduction of materials that are wholly alien to the surrounding localities, the substances are completely different, and the qualities are widely removed. These irregularities may have been made by collections of suspended materials being carried by the moving waters, and getting partially mixed with the substances that already existed in the locality. The vast accumulations of diluvial and alluvial deposits wholly destroy in very many cases any connection, even the most distant, with the subjacent rocks, and the understanding of the formations that are uppermost comes to be drawn from the substantial appearances that compose the uppermost depth of 3 ft. below the surface of the ground. Allowing 6 to 12 in. for the extent of the workings of cultivation, and 18 in. as the depth of the subsoil that will retain heat and moisture for the use of the upper land, the descent of one yard will comprehend all the space that can in any way influence the productions of agriculture. Any natural existences or affections below that depth do not enter into a legitimate comprehension of the soils and their qualities.

CHAPTER VIII.

Clayey Loams.—Cultivation.—Rotations of Cropping.—Manures suitable, and Value of the Lands.

A CLAYEY loam is a compound soil, moderately cohesive, in which the argillaceous ingredient predominates. Its cohesion is greater than that of any other loam, but less than that of pure clay. The other ingredient is a coarse sand, with or without a small mixture of the calcareous ingredient. In proportion as the clay abounds, the loam becomes stiff, cold, and heavy, or dry, porous, and very fruitful. Clayey loams mostly overlie the concreted beds of alluvial aggregations, which consist of mixed matters in clay, sand, earths, and gravels. The deposits are of great depth, and are generally found in moderately elevated districts which rise above valleys, and do not reach the height of hills. They are generally contiguous to alluvial flats, from which they form the ascent, by gentle and rounded undulations, to the neighbouring hills or highest grounds. The beds completely destroy any connection of the soil with the subjacent rock, and they lie indiscriminately over the primitive and secondary strata, and seem most frequently placed over the sandstones. The colour is generally black or red marly. In the midland counties of England they are found over the old red sandstone and all the existing upward formations, and very often get intermixed with the lias and clunch clays, and then the derivation of the soil is obvious, being the clay of these designations rendered friable by the mixture of alluvial productions. This is the origin of most soils of the name now being illustrated; the clay of the locality being mixed and pulverized by some extraneous matters of a local peculiarity. And these effects seem to have been produced by causes for which no satisfactory account ever may be given by any rational process of inquiry.

Clayey loams, being of the stiffish character of soils, require to be ploughed with a round deep furrow of 7 or 8 in. in depth, and in the months of November or December, for the crops of the ensuing year. The power of three horses will make the better performance, two of the animals walking in the furrow in tandem, and one on the unploughed land, with the advantage of the long end of the main tree, which renders the power of one animal equal to that of two in the furrow. The soil of clayey loam being stiff, and the furrow heavy, a considerable degree of strength is required to move the land freely from the proper depth. The average of climates allows the spring ploughing to be done in March, which is best directed across the land, as it cuts the slices and breaks the adhesion of the furrows. This work can be done by two horses, and all with the strong swing plough. The surface is then severely harrowed, next rolled, and harrowed again, when every weed and stone is very carefully picked by hand and removed from the field. Two weeks afterwards the land is ploughed longitudinally, harrowed, rolled, and harrowed, and picked of weeds and stones as before; and the same process is repeated in two weeks hence, which brings the season to the end of April, when potatoes and beetroot are planted. Potatoes are first sown, when drills are opened at the distance of 30 in. apart, by one furrow of the common plough drawn by two strong horses walking widely, and having for that purpose a main tree of 5 ft. in length attached to the plough. The begun-to-be-rotted farm-yard dung, in the quantity of twenty one-horse cart-loads to the acre, which has been heaped in a corner of the field, is deposited in the hollows of the drills, carefully spread along the intervals, and over it are placed by hand the cut sets of the potato tubers, and pressed by the foot into the due positions of 9 in. apart. The drills are then split, and reversed by a bout of the common plough, the length of the main tree allowing the left-hand horse to walk on the top of the unmoved drill, which does not disturb by the treading of the feet the sets of the plants in the hollows over the dung. In returning, each horse walks in a furrow, and the plough moves in an intervening hollow, and throws a heavy furrow of freshly-moved soil over the drill which was split by the downward furrow and thrown over the dung. The planting of the crop being finished in this way, the narrow tops of the drills are levelled by the lightest roll, which affords a level brainding of the crop.

From the beginning to the middle of May, beetroot is planted on the same preparation of the land, the seeds being dibbled by hand on the tops of the drills over the dung, or sown by the two-coultered machine. The ruts are filled by the light roller passing along the drills. Swedish turnips are sown till the end of May, and the seed is deposited in the fresh earth that is laid over the dung in the newly-made drills, by means of a double drill-sowing machine that is drawn by one horse and guided by a man. A rolling of the drills finishes the process.

Four earths, including the winter furrow, are most usually sufficient to prepare the stiffest green-crop lands to be sown with the crop; but much will depend on the constitutional texture of the soil, the arable management it undergoes, and the tools by which it is wrought. The plough, the harrow, and the roll, when timeously and judiciously used, are very amply sufficient to prepare any lands of common cultivation; yet much advantage is derived from the use of a heavy strong-tined grubber, which is drawn by four horses, and, with the alternate provision of circular and duck-footed coulters, breaks the square cuttings of the land, if any remain after the plough, and drags to the surface the roots of weeds, which are often cut into fragments by the coulter of the common implement. The better application consists in two workings of the grubber, each being interposed between the common operation of ploughing, rolling, and harrowing. The narrow points of the plough penetrate and raise the stiff under soil, which is very advantageously broken and pulverized by the varied action of the plough and the grubber. In this way one ploughing of the land may be saved, or, what is better policy, the land may be much improved in the pulverization by a working of the grubber added to the ploughings, for the value is inestimable of all stiffish green-crop soils being wrought to the very utmost possible fineness of tilth. On this purpose being effected, almost the whole expectation of a crop will depend, and any saving of labour that would tend to complete that object will be not only a very false economy, but will prove most positively injurious and detrimental; for the proper or imperfect working of the land not only tells the tale on the immediately following root crop, but it extends to every crop in the rotation, as each plant of the course requires a provision in the soil that is suitable to its nature, which can be conferred only by the duly performed fallowing of the land. The grass seeds that are sown with the first grain crop demand a very minutely-pulverized surface to suit their smallness of bulk; the oats and any other crops that may be sown on the surface require a large quantity of alluvium, raised by the harrowing, in which the seeds lie and germinate. If the land has been imperfectly fallowed, the soil will rise in a harsh and clammy state, and will break into crude particles without producing the powdery alluvium which is so much and so very justly prized for the reception of the seeds of plants. The climate of the season has much influence in producing this result; but the most favourable atmospheric influence will fail in yielding this effect in opposition to a badly-performed fallowing of the ground. It can only operate upon a favourable basis, and the more its influence is encouraged, the more beneficial will be the effects of its action; and this result depends on the state of the soil after being fallowed.

On the stiffest clayey loams of the first-rate quality the best rotation of crop will be—

1st year .	Green crops, in potatoes, beet, and Swedish turnips.	3rd year .	Hay.
		4th „ .	Oats.
		5th „ .	Beans, a part in peas.
2nd „ .	Wheat or barley.	6th „ .	Wheat.

This course is adapted to the very best quality of soil, and to a benignity of climate which permits the preparation of the land for beans in the fifth year by a grubbing and a slight manuring. Barley being used in the second year, the number of plants includes every useful vegetable, and those which are of the most valuable kinds. When lime is applied, it may be very advantageously spread on the bean gratten, and mixed with the soil by harrowing, when the land is ploughed by one furrow for wheat.

Clayey loams of rather an inferior quality are found overlying the sandstone or red marl, and being somewhat mixed with the marl, the soil becomes a marlaceous clayey loam. The quality is very good, but, the texture not being sufficiently viscid for the growth of wheat and beans, the course of cropping must be more lenient and less scourging for the land. The best rotation is the following :—

1st year . .	Green crops, potatoes, beet, and turnips.	3rd year .	Hay.
		4th „ .	Pasture.
		5th „ .	Oats, a part in peas.
2nd „ . .	Barley.		

The value of this rotation is very great, and admits of a very large application, so much so that many very eminent practical agriculturists have reckoned it suitable for any soils in the world, with the variations that are induced by local peculiarities in fostering the vegetable growths. The two years in grass are found to be most particularly renovating to the land in producing firmness of texture, and the vegetable freshness arising from the decay of the roots and leaves of the grassy herbage, which is incorporated with the earthy ingredients of the soil. This preparation of food exceeds in value any artificial application in the shape of manure, as the reduction is most minute of the earthy vegetation, and the commingling becomes of the necessary intimacy. On these two states of existence the value of all combination depends for fruitful purposes.

Farm-yard dung, as a manure, is most appropriate for the stiffest clayey loams, as the clammy adhesion barely permits the action of bones and guano, or any artificial manures. But they are used, and very frequently with success. On the second quality of these soils, or the red marlaceous loam, all the auxiliary manures exert their utmost influence, and the effects never fail to vindicate the prestige of the reputation of these highly-useful substances. The marly part of the composition of the soil is particularly favourable to the action of any finely-comminuted matters, as they find similar elements with which the ultimate combination is effected, and the molecules of the different substances are able to effect a reciprocal affinity. The warmth of the composition of the soil is a very chief requisite for the action of extraneous manures, and it is amply enjoyed by the red loams of the marly sandstone. This property in soils of receiving and retaining heat is a very large part of the cause of fertility, and it is essential to the encouragement of the action of manures. The number, variety, and mixture of the ingredients constitutes this property in lands, and also forms the cause of the fertilizing development of manures.

Lime, in the quantity of 200 bushels to an acre, operates very advantageously on the stronger loams of the clayey denomination. The caloric which it imparts to the land finds a conductor in the comminuted animal and vegetable matters which constitute the loamy nature, and it is imbibed in a quantity that is sufficient to overcome the repulsive quality of the clay, which is the obstacle to the action of lime on all clay lands. The clayey loam is thus thoroughly warmed and heated, without which no very large fertility ever can exist or be promoted. Hence the quantity of lime must be large, and used during dry weather, and the substance in a finely-pulverized condition. In these forms both the land and the lime are most likely to receive and impart mutually the quality that is possessed by the one and which is wanted by the other. The use of lime to the land in this way should not be deferred beyond every third return of the course of cropping, or in each period of fifteen and eighteen years.

The value of the clayey loams that have now been described holds the highest figure in the scale of the relative productions of land. The yield of the crops is large, and the kinds of produce are the most valuable that are known; the expense is not greater than that of common cultivation, and the soundness of the land ensures the quality of the articles that are produced. On these lands no manure is ever wasted, nor is any labour misspent; the soil is always grateful, and no diminution is ever evinced of a sense of the obligations that are conferred upon it. These loams are capable of producing the average crops of four quarters of wheat per acre, six quarters of oats, and the same quantity or more of barley, four or five quarters of beans and peas, and two tons per acre of clover hay, ten tons of potatoes, twenty tons of turnips, and twenty-five tons of mangel-wurzel. These quantities will form a very fair approximation in England, and will require the first-rate cultivation of the land to produce them. In Scotland the returns will be larger, especially in oats and root crops, as both the soils and the climate of that country are peculiarly favourable to these plants; and the mode of cultivation that is practised is superior to the management followed in England. The average rent per acre of the two sorts of clayey loams now specified may be written at 30*s.* to 40*s.*, or probably better at 28*s.* to 35*s.* Extreme cases only will reach 40*s.*, and in Scotland some exceptions will nearly double that sum; but the general rule is not affected by local peculiarities where the natural formation is assisted by some advantageous contingencies, which probably do not reach beyond the extent of one or two farms of moderate size. A near convenience to markets is a very considerable acquisition, as is the ready access to lime and other sources of manure. A good aspect in the situation of the lands is an object of much attention—high or low, level or declining—and the quantity and quality of the exhalations that may be expected to arise from the solar influence on the surface of the ground. These circumstances are often so powerful as to overturn the natural qualities of many lands, and not unfrequently they correct constitutional defects. The atmospheric peculiarities are the regulators of the plants that can be profitably grown on any lands; but the loams now described are generally placed in favourable situations, where the vegetables stated in the rotation are conveniently grown.

It has been till now omitted to give a list of the grass seeds to be used for hay and pasture.

For hay, per acre,—

Ray grass . . .	1 bushel.	Trefoil	4 lbs.
Red clover . . .	12 lbs.		

For hay and pasture, per acre,—

Ray grass . . .	$\frac{3}{4}$ bushel.	Meadow catstail . .	4 lbs.
Cocksfoot . . .	$\frac{1}{4}$,,	Red clover	10 ,,
Meadow fescue .	4 lbs.	Trefoil	4 ,,

CHAPTER IX.

Sandy Loams.—Cultivation of the Loamy Varieties of Arenaceous Soils.—Rotations of Cropping.—Manures suitable, and Value of the Lands.

The sandy class of loamy soils is much more comprehensive than the last order of lands, and reaches over a much larger extent of country. Sand is a much more abundant ingredient than clay, and admits a much larger variety of mixture with other substances, owing to the very minute reduction of the particles of its composition. Silica, or the original earth of flints and sand, is by some thought to constitute the basis of the globe, and is found in every formation that leads the ascent of the geological staircase to the most recent alluvium in the subaërial deposit, where it acts a powerful part in distinguishing the various characters of cultivable grounds. The fineness is not a little variable; large or small, gritty or pulverized, according to the actions it has undergone, from the breaking up of the original formations to the deposit of the alluvial beds which most generally support the arenaceous grounds of cultivation. These huge beds of concreted alluvium are mostly superimposed on the primary and transition strata of the globe; the secondary rocks rise much higher, and then the soils have a more immediate connection with the mineral aggregation. The sandy soils that overlie the alluvial beds of deposit are much the best in quality, as the quantity of mixed ingredients is the greater, arising from the agitated and commingled production of the alluvial formations, of which the deposits now mentioned form a very apt illustration. Clay and gravels constitute a large part of the mixture, and confer upon the upper soil the benefits of their peculiar attachment. These alluviums form almost the whole extent of Norfolk and Suffolk, and are formed of clay, sand, and gravel. The chalk sinks below these tertiary formations, which afford many modifications of the upper soil. As the beds themselves differ in the properties of composition, so the lands of cultivation are variously qualified, and some operations on the surface subsequent to the location of the deposits, may have very much altered and modified the character of the primary constitution. Inundations may have changed the upper stratum by the agency of ablution, partially removed the existing materials, or wholly introduced a new sedimentary deposit. These alterations may belong to the alluvial period of location, and the underlying beds may be the diluvial productions; but on this point the best authorities are not reconciled.

The aggregated beds of the diluvial or alluvial deposits support the loamy sands of the best quality, and are found chiefly in districts that are low in the geological staircase, and where the tertiary epoch had formed the largest development of its power. These formations are found over the extent of the British Isles, the best quality being situated in the counties of Norfolk and Suffolk, where the soil is mixed with the chalk and with a marly clay that has been formed by the mingling of the chalk with the aluminous earth. These soils form a middle step between the clayey loams, which have been treated of, and the sandy loams properly so called, which contain little mixture beyond the siliceous earth with the exuvial sediments. The depth is generally shallow, lying on a closely-compacted bed of clayey or gravelly earth, but which forms a favourable substratum in the valuable points of moisture and caloric. The absorbent powers are able to conduct downwards without harm the water that would otherwise prove detrimental, and to retain a quantity that is sufficient for the future vegetable growth, without preventing the heating of the ground by caloric at the proper season. A large part of the cause of fertility rests on this invaluable property of the subsoil of lands. The rotation most adopted is :—

1st year	Turnips.	3rd year	Clover.
2nd „	Barley.	4th „	Wheat.

This course of cropping is too short for any quality of land, and the fact has been often acknowledged, though the force of custom yet prevails over the power both of sense and conviction. The grass layer of one year is too loose for wheat, and the frequent sowing of turnips has been found adverse to the general success of that invaluable crop. By adding a second year in pasture the ground will be very usefully consolidated, thus :—

1st year	Turnips.	4th year . .	Pasture.
2nd „	Barley.	5th „ . .	Wheat and oats.
3rd „	Hay.		

These lands are prepared in the cultivation by the processes that were described in the last chapter on Clayey Loams. The ploughing is not so deep, nor are the workings so heavy for the implements or animals. The texture of the soil admits the use of every kind of artificial manures, which exert the full effect of their power on the loams of sandy composition. Bones, in the quantity of sixteen bushels an acre, and guano in 5 cwt., will raise very beautiful crops of turnips, which, one-half being consumed on the ground by sheep, never fail to put the land into excellent heart for the following use of its powers. The quantity of farm-yard manure that is made in the feeding yards is applied to a part of the turnip fallows, and these, being treated with bones or guano, in the next rotation, will change the manure on the same grounds, and afford a healthy variety of nourishment. The plants sown may also be changed, and thus effect a complete alteration in every respect.

These loamy soils of the chalky and clayey modifications are the most productive of the sandy lands, and the value may be stated at 25*s.* to 30*s.* an acre. The general figure may approach the latter sum, and an inferiority will sink to the former. The best quality will yield four quarters of wheat per acre, and the largest crops of turnips. The barley is always of the best quality, and much esteemed by the brewers.

The quality is rather inferior to those mixed soils of the sandy loams that overlie the tertiary deposits, and where no convenience occurred of being mixed with the clays and chalks, which are wholly removed from the contiguity of formation. The quality is still most pre-eminent, and the soil is, of all others, the most productive of sound grassy herbage. The colour is mostly red, and sometimes black, with the subsoil similarly coloured, and formed into a hardened, and yet porous aggregation, receiving and using moisture and caloric in the most beneficial application. The exuvial matter is large in quantity, owing to the primary stratum being favourable to the liking and growth of the organized creation which lived and died upon the surface, and afforded the material of humus, which has been described, and stated to constitute the fertility of lands. In this way the subsoil has exerted a most marked influence on the quality of the cultivable stratum, not by directly affording fertility, but by inducing the elements to congregate and leave their bodies as a decomposing residuum of earthy débris from animated life. This quality forms the very peculiar excellence of sandy loams, that the siliceous part very readily receives caloric, radiates it quickly, and retains it by means of the finely-comminuted earthy ingredients that have been supplied by organic decomposition. And this quality, both in kind and degree, may be very safely said to depend on the kind or repulsive nature of the subsoil.

One general rotation of cropping applies to these prime sandy loams, viz. :—

1st year	Turnips.	4th year	Pasture.
2nd „	Barley.	5th „	Oats.
3rd „	Hay.		

This course may be safely said to admit of no improvement on these lands; the grass crops are most particularly valuable, both in the quantity and quality, yielding a most nutritious dried provender, and a pasture for vagrant animals that is sound, wholesome, and most agreeable to live stock of every kind. The growth of hay is large, often exceeding two tons per acre, and containing in the mixture every useful grass. The weight of turnips is the highest figure, that of barley being six or seven quarters, and of oats fully eight of the same measure. The average value per acre will be near to 30*s*., say 26*s*. to 28*s*.

These sandy loams allow the very fullest development of the action of artificial manures, as the texture is fine and the composition warm, which are the two essential requisites to the agency of all concentrated essences. Guano is best used over a half allowance of farm-yard dung, as, by its quick and spirited action, the tender germination of the turnip seed is pushed into the state of rough leaf, where it is safe from its deadly enemies, which devour the seedling leaflets, and kill the plants. It is of the greatest advantage to have the manure and the land in a suitable condition to push the growth of the turnip plants quickly and steadily beyond the state of danger. When this object has been attained by the turnip plants assuming the rough leaves, the more durable aid of the farm-yard dung succeeds the action of the guano, and continues during the remainder of the season to afford a vigorous sustentation to the growing plants. Bone manure may be used in the same way, by applying half the common quantity over the lessened allowance of farm-yard dung that is spread and covered in the drills; or it may be applied by itself in the proportion of 16 bushels to an acre, and sown with the turnip seed in mixture by the two-ridge drop drill machine.

The following list of grasses is required for the course of five years on sandy loams :—

	Per Acre.		Per Acre.
Ray grass . .	$\frac{3}{4}$ bushel.	Poatrivialis .	2 lbs.
Cocksfoot . .	$\frac{1}{4}$ "	Red clover .	8 "
Meadow catstail	4 lbs.	White clover .	4 "
Meadow fescue	4 "	Trefoil . . .	4 "
Poapratensis .	2 "		

An inferior modification of sandy loams is found lying on the same diluvial bed, and seemingly composed of the same materials. The upper stratum is more shallow than that of the last-mentioned deposit, and the quantity of humus is deficient. The texture is weaker, and all the crops are much less bulky. The only difference in the management from the best qualities consists in prolonging the pasture of the ground, as under :—

1st year . . .	Turnips.	4th year	Pasture.
2nd "	Barley.	5th "	Pasture.
3rd "	Hay.	6th "	Oats.

The grasses to be sown are, per acre,—

Ray grass . . .	$\frac{1}{2}$ bushel.	Crested dogstail .	4 lbs.
Cocksfoot . . .	$\frac{1}{2}$ "	Red clover . . .	8 "
Meadow fescue .	4 lbs.	White clover . . .	4 "
Meadow catstail .	4 "	Trefoil . . .	4 "

These light sandy loams are uncommonly favourable to the growth of turnips and to the action of every artificial manure. For sheep consuming the turnips on the ground no soil can be compared with them; in wet or dry weather the land affords clean food and a comfortable lodging, which are essential to the thriving of animals. The pasturage is always grateful to the taste, sound in its effects, and nourishing to every animal of the farm. The general produce will be one-fourth less than of the last-mentioned loams, and the value may be stated at 15*s.* to 20*s.* per acre.

The loamy soils that have been described are of the alluvial fresh-water formation, and constitute the uppermost deposit that has been made on the face of the globe. But in south Britain, where the highest stratifications prevail, the third sandstone in the ascending series, which supports the chalk, has been denuded by the removal of the cretaceous deposit, and exhibits soils of loamy sand, which have proceeded from the decomposition of the rock after it was exposed by the denudation. The upper part of this rock is called the green sand, and is found in association with the chalk in all places of the underlying exposure. From Cambridgeshire, through the county of Bedford, into Berkshire and Buckinghamshire, the surface of the deposit forms land of various qualities, sometimes being loams of very fair productive powers, and much valued as garden moulds, and often constituting soils of a very poor arenaceous description. The name is derived from the soil containing the green silicate of iron, which imparts a ferruginous quality that is not very friendly to vegetation. The soil is of fair quality where earthy ingredients have occurred and have been intermixed; but its general properties are inferior to the sandy loams of fresh-water alluvium.

The last-mentioned system of cropping, and the grasses to be sown, apply most strictly to the loams of the green sand, for, in both formations of surface ground, their very close similarity admits of the same course of cultivation being pursued. On the very best sorts of the land the course of five years may be very advantageously followed; but on the larger portion of the soils, the rotation of six years will be most beneficial. An incalculable benefit is conferred upon the land by the turnips being consumed on the ground by sheep ; the urine sinks into the land, and the dung is mixed with the soil in the most intimate manner by means of the narrow-pointed hoofs of the animals repeatedly treading on the surface. The ground is also consolidated, which is a very large benefit to light lands. All sandy lands are favourable to the action of artificial manures, and the crops of turnips, if not very heavy, are always close and abundant.

Beneath the green sand there lies an earth of the hills, or an argillaceous deposit, called "gault," and below it is found the lower portion of the rock called "the iron sand." This lower arenaceous deposit has been denuded and exposed by the removal of the chalk, the green sand, and the gault clay, under all which formations the iron sand is placed. The soil is found chiefly in Surrey, in the valleys below the chalk, with the rocky escarpment overlooking the wealden formation of clay in the southern aspect. Round the edges of the sandstone deposit an overlapping is formed with the surrounding clays of the plastic, London, and wealden formations, and loamy soils of fair quality are constituted by the mixture of the sand and the clays and the subsequently-created humus. But on the elevated central parts of the sandy deposit a very barren soil prevails, possessing a ferruginous quality that is imparted by the black oxide of iron, which abounds in the composition of the land. This mineral ingredient being added to the sandy particles of the formation, forms a soil that is much too violently heated for the growth of vegetation. Accordingly these sandy lands are generally very barren, in many cases not worth the cost of cultivation, and the soils remain in a state of entire inutility. In descending from this condition of utter barrenness to the good loams that are formed by the junction of the sands and clays, there occur many cultivable soils that rank very low in the scale of value, and which are rendered unproductive by the very porous sands and the oxide of iron.

The best loams of the iron sands are cultivated in the course of five years, which has been very fully detailed and explained. The rotation of six years may be, in many cases, very advantageously adopted, as it tends to consolidate the very loose ground, and adds to the vegetable freshness in the soil by the decay of the leaves and roots of the grass plants. On the common sandy lands the early heat of a dry summer is generally fatal to the progressive growth of any vegetable; the land is heated beyond the bearing of organized life, and the plants wither and die. This is most commonly the case with the crop of barley, which often never progresses beyond the half protrusion of the ear, which is stopped in the growth, fags, and the pickles of the grain are not half filled or matured. In some instances the ears never appear at all.

But these lands are highly favourable to the action of artificial manures, and turnips in fair crops are raised by the use of bones and guano. Being consumed on the land by sheep, the ground can be sown with winter rye, which attains a leafy growth, to cover the land and defend it from the heats of the early summer, which generally prove fatal to the crop of barley, as the soil, being moved by the ploughing for that plant, readily admits the penetration of heat and drought. Rye is naturally adapted for sandy lands and a hot locality, and it produces a larger bulk of straw than any other culmiferous plant that is known. It is, therefore, much the most profitable seed-bearing grain crop for the iron sands, as the straw is bulky, and very suitable for thatch, and the grain usually bears the price of barley. The weakness of the soil requires several feeding crops to one of the seed-bearing kind, and may be arranged as follows :—

1st year .	Turnips.	4th year . .	Barley.
2nd „ .	Rye.	5th „ . .	Clover.
3rd „ .	Winter vetches.	6th „ . .	Pasture.

Or—

1st year. .	Turnips.	4th year . .	Winter vetches.
2nd „ . .	Spring vetches.	5th „ . .	Oats.
3rd „ . .	Rye.		

Or—

1st year . .	Turnips or rape.	4th year . .	Cole.
2nd „ . .	Rye for feed.	5th „ . .	Oats.
3rd „ . .	Winter vetches.		

The best experience recommends two to four feeding crops to one that perfects the seed and ripens the crop.

The value of the lands belonging to the iron sand must be placed at a very low figure; that of the lowest quality in cultivation at 8*s*. or 10*s*. per acre, and of the best loams at 10*s*. to 15*s*. But few farms are composed wholly of these sandy lands, as the formation is very much intermixed with the clays of the marine formation, which are interpolated in the valleys, where the very clammy and viscous texture of the aluminous earths forms a most remarkable contrast with the sands of the green and iron designation. The complete removal of the superimposed chalk has exposed the subjacent sand, and the view of its composition is both curious and interesting. The growing of turnips on the sandy loams is very useful and advantageous in conjunction with the clayey grounds, as it admits of keeping live stock, without which the farming of any lands is at best very disagreeable, and attended with little advantage. With this view these sandy lands of the middling quality are preferable to the clays of the marine formation, though the latter be more productive, both of grass and grains, of the kinds which their nature enables the soil to produce. Hence it is always very justly considered that every farm of land which adjoins the sandy deposit has attached to it a quantity of loamy ground, such as it is, in order to relieve the very irksome tediousness of the cultivation of clay grounds. A variety of produce is obtained, which mixes the cultivation, and secures the chances of marketable values.

CHAPTER X.

Gravelly and Chalky Loams.

Gravel is understood to be a diluvial deposit, and is formed by small pebble stones. The size varies from that of a small pea to that of a cockle. They are often intermixed with sand, clay, loam, flint, pebbles, iron ochre, and other mineral bodies. Gravel is older than the alluvial formation, and some very curious and important characteristics are implied in its diluvial origin. Thick deposits of clay, sand, and pebbles are found on the very summit of hills as abundantly as in the valleys. Fragments of rocks wholly different from those in the vicinity lie in valleys, on hills, and even on islands, as in Staffa. These fragments are found solitary, or buried in clay, sand, and gravel, in very great abundance, and unlike to any rocks within one hundred miles of them. The largest blocks, or boulders, lie at the top of the deposition, resting on the sand, or smaller gravel; successive depositions can rarely be traced—the mass lying indiscriminately, large and small bodies, light and heavy, being laid together, without any order or arrangement. Amidst such confused masses, bones of land quadrupeds, mostly or entirely of extinct species, and even of extinct genera, occur in abundance.

In order to account for these characteristic phenomena, it has been found necessary to suppose great changes of physical geography, or physical processes not seen in daily operation, such as extensive displacement, and change of the level of land and sea, unexampled floods of water, surprising alterations of climate, or movements of glaciers in situations where they could not now exist. And one general overwhelming inundation has been mentioned, as being able to overcome the lesser inequalities of the surface level, but modified in its course by the larger ranges of mountains and valleys.

It is an essential character of gravel that it shall contain rounded stones, "extraneous" to the place where they are found; otherwise the decomposition of loosened rocks and strata near the surface will be confounded with it, as has often happened in the description of countries. The earthy matters found in gravel vary in all degrees from clay to sand; and according to the prevailing quantity of these matters the gravel gets its distinctive name. Thus, to sea-shore gravel, where the action of the waves hinders any mixture from being retained, the term of "clean gravel" is applied; where there is a considerable portion of clay, we use the name "clayey gravel;" where sand is found, it is called "sandy gravel;" where loam exists, the name of "loamy gravel" is used, and so on. Some writers add the term "alluvial" to the above terms of sand, loam, and clay, using it in the strict and proper sense, as denoting matters worn, moved, dispersed, mixed, and deposited in water, in distinction from the regular or undisturbed matters of the terrestrial strata, which show evident marks of having been deposited in a fluid, the perfect homogeneity of the lamina of the strata, and their vast extension without rude or accidental mixtures, proving that the laws which governed the two kinds of terrestrial deposit were not less distinct and marked than are the processes of the precipitation of matters before mechanically mixed and suspended in a fluid, and the crystallization of substances from menstrua supersaturated therewith. During the deposition of the strata all was tranquil and quiet, except the movements of animated beings which occupied successively the vast subaqueous plains of strata; during the formation and deposition of the gravel of every description all was violence and confusion, and apparently so continued for a long period of time.

It is an important problem in geology, to settle the point "whether gravel is anywhere found under regular and undisturbed strata." Many writers have asserted this to be the case; but Mr. William Smith and others, after a very long and most laborious investigation, have come to the conclusion that no such case can be pointed out in England. It is very true that indurated masses occur with some few rounded stony fragments in mixture, which are of difficult discrimination from the form of stratification; but these doubtful masses have been continued in character "downward" to such gravel beds; and nowhere are any regular strata ever found upon these doubtful masses, where due caution is used in making and extending the observations. Siliceous or gritstone beds and rocks have been mistakenly classed with gravel, being composed of distinct grains of silex or crystallized quartz in various sizes, and mixed and indurated together. But an attentive examination of their beds and accompanying strata, and of the newly-cut or broken faces, and a comparison of them with the heterogeneous mixtures and irregular stratification of the real gravel rocks, as they appear in beds of immense thickness in many midland counties of England, will easily distinguish the coarsest of the gritstone strata from the superficial mixtures above mentioned, and from alluvial or water-worn mixtures of any kind. A uniform and constant law has regulated the formation of silex, and of coarse as well as of fine gritstone, and sufficiently prevents their being confounded with the water-worn gravels. Accumulations of gravel are to be distinguished into native and foreign, according as the pebbles, the earth, and the extraneous bodies among them can be referred to known and adjacent strata, or consists of stones and earths not elsewhere found but in very distant countries. Except on the sea-shore, where the gravel is formed by the waves acting upon the fallen cliffs in fragments, the gravel of no spot corresponds with the strata on which it is lodged; and where it does very rarely occur, it will be found that the strata extend to the east or south-east of the place where the gravel is lodged; and this is explainable upon the principle that the general moving of the native alluvia has happened from the south-east to the north-west quarter. The coarse and irregular gritstone strata occur beneath the carboniferous system or coal measures, but do not seem to indicate, as Mr. Kirwan thought, the near approach to the fundamental rock of granite. It is of very great importance to discriminate accurately the alluvia found in different parts of any country, and to trace their connection with the regular and continued masses on which they rest, and from whence they have been torn.

When beds of gravel approach the surface of the earth, the mass forms a gravelly bottom, in agricultural language; when they reach the open daylight, a gravelly soil is formed, and when the size of the stony particles exceeds the size of the hen's egg, the land is called "stony." Pure gravelly soils have a substratum of the same materials, more gritty and indurated, and deficient in the mixture of animal matters which the upper stratum has derived. When it rests upon clay, it forms very often a "weeping" soil of very poor quality. But the pure gravels are in many instances very fertile; the open texture admits moisture freely, and the under soil being compact, retains it in due quantity, and gives it out as wanted for the purposes of vegetation. In some cases, both the upper and the under soil are too loose and open, and yield the moisture too freely; and in dry seasons the crop is scorched. Sound gravelly soils are very favourable to the growth of turnips; the pebbles retain a very agreeable coolness in hot weather, and also afford shelter to the rootlets of the plants during violent heats. Very good barley is produced by gravelly lands; the skin is always very thin, and the farina is white and clear in the colour. The quantity is also very fair on the lands of medium quality. The straw is not bulky, but the grain is always fine and saleable. Like most soils, the quality of gravelly lands depends on several contingent circumstances, as the quality of the substratum and the openness or compactness, and the quantity and quality of the vegetable and animal remains which have lived and died on the surface of the ground; and also upon the way or mode in which the different materials are chemically combined in the relative and comparative quantities. When immediately mixed with clay, a soil is formed that becomes very difficult of tillage, and also of drainage, from the fact that the water has very many oozings and filtrations; as beds of sands, or of mixed sands, most generally underlie the mass of clay and gravel. The pebbly stones get very firmly imbedded in the clay during dry weather, and present a very tedious resistance to the action of agricultural implements. And, as may be readily supposed, the stony soil is very grating for the iron part of the implements that moves below ground, especially when the subsoil is composed of a bed of indurated dry clay, in which are very firmly imbedded large quantities of pebbly stones of various sizes.

The gravelly lands of the best quality form the turnip soils, in the true sense of the word; but it requires a very peculiar mixture of the earthy ingredients to constitute the land of that special designation. They are incumbent on a huge bed of diluvial detritus, that is composed of clay, sand and gravel, and modified into the condition of retentive penetrability. This state is not often found, and consequently the lands of the first degree are not numerous. The working of the soils has been described under the head of sandy loams, and the best rotation of cropping will be—

1st year	Turnips.	4th year	Pasture.
2nd „	Barley.	5th „	Oats.
3rd „	Hay.		

Artificial manures find a very agreeable field of action in gravelly loams, and the desired effect is always attained. The produce of the crops is lighter than on the best loamy sands, and must be written less by one-fourth part. The value per acre may be 25*s*. to 30*s*.

The inferior or second-rate quality of gravelly loams is much more extensive than the last-mentioned lands, and require a more lenient system of management. The course of six years must again be introduced as under:—

1st year	Turnips.	4th year	Pasture.
2nd „	Barley.	5th „	Pasture.
3rd „	Hay.	6th „	Oats.

On all light loamy soils that are placed in high latitudes beyond the proper maturation of barley, oats are sown in the second year after the fallow crop, and answer well.

The grass seeds are to be sown as under:—

	Per Acre.		Per Acre.
Ray grass . . .	½ bushel.	Dogstail	4 lbs.
Cocksfoot . . .	½ „	Red clover	8 „
Meadow fescue .	4 lbs.	White clover . . .	4 „
Meadow catstail .	4 „	Trefoil	4 „

The gravelly loams of the best quality may be reckoned a diluvial deposit, and the inferior order of soils to be a later alluvial formation that has been purged of the earthy ingredients by the action of water, and has lost much of the cemented aggregation. A dry hardened clayey earth is the most favoured matrix of gravel, in which the pebbly materials are imbedded in a near contiguity, if not altogether touching each other. This matrix has not proceeded from the deposit of fluviatile operations, but from a power of much larger extent and of a more comprehensive agency. The formation of the beds must have occupied a large amount of materials, a strong power of aggregation, and a prodigious force of locomotive agency. The elevation of the deposits implies a power of vast extent, and which had covered the earth very deeply over valleys and mountains. The deposits had been moved in huge masses, and seem to have been dropped and located by a promiscuous carelessness. In no case of cultivated lands is there to be seen the intimate connection of the soil and subsoil in so favourable a similarity as in the best gravelly loams, where the qualities of each stratum are mutually dependent, and reciprocally beneficial. It is the coolness that is combined with warmth which forms the very peculiar excellence of the diluvial gravels, a quality of all others the most difficult to be obtained, and which is of all others the most conducive to vegetable growth. The whole amount of fertility is conferred by its regulation and appropriate action.

Chalky Loams

lie on the tops of the chalk hills, where exposure has decomposed the feebly-aggregated mass of the carbonate of lime, and a mixture of earth and some little humus has occurred. The soils are few in number, and are rather loamy or earthy chalks than loams, the latter ingredient being very weak and scanty. A large part of chalky surfaces are wholly worthless, and beneath cultivation, and the best qualities only reach a fair minimum of value. The surfaces of the chalk and of the underlying third sandstone, have been swept very bare by the denuding flood or other agency; little or no earthy sediment has been deposited, as the tops of the hills are high, and the transition of the watery elements over the elevated situations would be quick, and little time would be afforded for deposits being made. Accordingly these heights are very bare of earths, and some few places only are worth cultivation.

Chalk, being a loose formation, is devoid of the agreeable and sweetening quality that is possessed by the more compact limestones, and which is found to be very conducive to vegetable growth. The reduced materials are harsh, meagre, and gritty, and have little active reciprocity for other substances of any kind. It imbibes only one-half of its own weight of water, and gives off moisture very freely, nearly as fast as sand, and three times faster than alumina. The soil is very hot, from the quick radiation of caloric by its particles, and the moisture being easily evaporated, the state of the ground becomes too much heated for the health of vegetation. Consequently all the growths are very puny and stunted, and seldom attain a condition of maturity either as grains or dry fodder. The dry pulverulence of the soil is not even favourable to the growth of turnips, nor to the action of artificial manures; the plants become yellow in colour, wither, and often die altogether. The warmth of the soil is wanting in the dampness that is inherent in loams arising from the exuvial matters which form the essence of the composition. The meagre grittiness is repulsive of any reciprocal affinity, and produces no fruitful combinations.

The best qualities of chalky loams, or earthy chalks, are best used in a course of six years:—

1st year	Turnips.	4th year	Pasture.
2nd "	Barley.	5th "	Pasture.
3rd "	Hay or pasture.	6th "	Oats.

The grasses to be sown are—

	Per Acre.		Per Acre.
Ray grass	½ bushel.	Sheep's fescue	4 lbs.
Dogstail	4 lbs.	Red clover	6 "
Hand fescue	4 "	White clover	4 "

The best chalky loams may be very advantageously used in this way; but the upper grades of inferiority present an impossibility to the forming of a grassy sward, or even procuring a seedling vegetation. Sainfoin is well known as a herbaceous plant indigenous to chalky grounds, and very peculiarly adapted to the soils of that formation. The roots penetrate deeply, and spread widely, and tend most powerfully to bind the loose earth, and form a consolidated stratum. Very large improvements have been made in this way, yielding a most grateful pasturage to sheep, and imparting a firmness to the soil that holds the roots of future crops. The soil must be enriched by two to three feeding crops, as turnips and vetches, and then sown with barley as a seed crop, receiving at the same time the seeds of sainfoin at the rate of two pecks on an acre. The first year's crop may afford a cut of hay, probably not bulky, but may be very useful as dry provender. The ground is then pastured by sheep during eight or ten years, or so long as a tolerable bite of herbage can be got by the sheep. The land is then ploughed and cropped as before, and relaid with sainfoin.

These sainfoin layers, when long continued, have encouraged and propagated the wire-worm, and have caused much mischief in that way. The time of pasturage is curtailed, and a mixture with the sainfoin of such perennial grasses as are suitable to the soil, is recommended. With the exception of sainfoin, the nature of chalk does not seem to be favourable to vegetable growth of any kind; the natural grassy herbage is particularly puny and misthriven, and indicates both a want of sustenance and a radical adversity of composition. This fact is very generally acknowledged, and seems to be established beyond dispute. It is advisable well to consider this truth in any legislation for chalky soils, or any near alliances of that formation, as feebleness of aggregation and barren meagreness pervade all the subordinations of the deposit, and infect every quality of the cultivation. Though it be a carbonate of lime, the nature falls short of the general excellency of that neutral salt.

CHAPTER XI.

Peaty Loams and Fenny Soils.—Cultivation of the Lands.—Rotations of Cropping.—Manures suitable, and Value of the Lands.

PEAT or moss is generally considered to be an alluvial deposit that has been formed by a vast number of trees, leaves, and fruits, assisted by the decay of aquatic plants, and by the earthy matters carried by rains and floods to the places of formation. This theory of its formation is very inconclusive, though in some particular cases it may probably account for some few appearances, while for others it certainly offers no satisfactory conclusion. Peat occurs in vast quantities in the northern parts of the kingdom, in beds of vast extent, of depths varying from a few inches to that of several yards, and of many qualities, from the loose incoherent moorish peaty and turfy soil to the solid mass that is cut and dried for fuel. Turfy soils contain a large mixture of earths, and, when burned, they leave a great quantity of ashes; many soils of that composition are under regular tillage, while others are so poor as to be unworthy of any attention. Solid peat or moss may be comprehended under two heads—a black solid pulpy mass, and a light brown formation of a spongy fibrous texture, and evidently of a different quality and different circumstances of formation from the other, though both are found in closely-adjoining situations. In some places it is loose and crumbling, from being mixed with the leaves and branches of trees; in others the texture is wholly fibrous from top to bottom, or of that nature at the top, and more solid and inflammable at the bottom; and very often the whole mass is a black bituminous substance without any marks of organized remains, and capable of being cut into bricks and dried for fuel. Peat has been called a mixture of clay with calcareous earth and pyrites, with some common salt; but this mixture must belong to particular formations. Sulphates of soda and of magnesia occasionally occur and deteriorate the combustible quality. Peat contains in itself no fertilizing properties; gallic acid forms a full fourth of its constituent parts, and the other parts that might assist vegetation are locked up or rendered useless by that noxious ingredient. No animal or vegetable matters are contained in the mossy substance for future decomposition; the peculiar state of its formation does not allow any process of fermentation or putrefaction, and it moulders and disappears without action or energy of any kind. Moss and vegetable mould have been reckoned homogeneous substances, altered by the different circumstances in which they are placed, and the external agencies to which they are exposed; but this fact, when granted, gives no reason for moss and mould being produced in adjoining situations, where little or no difference in external circumstances would be supposed to exist. Formations of peat chiefly abound in moderately cold latitudes; to form it, dampness and astringency are required, and the water must be antiseptic, which is said or thought to derive that quality from the subsoil. But we are equally in the dark whether the astringent and antiseptic quality be derived from the subsoil, the climate, the plants that grow on the place of formation, or from the combined influence of all these causes. The scientific reasonings of theorists are generally overturned by facts and by the appearances of nature; and after all the opinions and conjectures that have been put forth, the more reasonable and natural conclusion would seem to be, that moss is an original formation, augmented, like other formations of a similar nature, by physical agencies still going on, and that it has been produced and located by causes for a solution of which our imaginations may ever search in vain.

The cultivation of true peat is a hopeless undertaking, notwithstanding many repeated attempts, and even a much-vaunted success. It may be safely asserted that such attempts are altogether futile in every case where the solidity of the formation does not carry the weight of the animals of draught: spade labour can be applied, but the results have not been found to be corresponding. Moss generally, though not always, lies in concavities; and on the surrounding higher grounds, which often cover very large extents of country, there is found a stratum of peaty earths that is of greater or less depth in different situations, and of which the quality is extremely various. The texture is most generally loose and incoherent, and varies from the thin vegetable stratum of a few inches in depth, to the black and waxy loam of a foot or more in bulk, passing in the interval through very many gradations that improve in quality and progressive vegetable usefulness. The subsoil is most generally a white gravelly sand, or a very compact clayey gravel, and wet or dry according to the climate and the adjacent geological formations which discharge water into the heterogeneous mass. These soils occur only in districts of the primary formation, as in the north-western counties of England, and in the north of Scotland. In that country moss lies upon the very oldest formations of granite and gneiss, and the surrounding subsoils, which support the cultivable lands, are formed of huge beds of diluvial or alluvial aggregations of very mixed materials. The situations being elevated, and the latitude northern, the climate rarely permits the maturation of barley, but where it does, the following rotation must prevail:—

1st year	Turnips.	4th year	Pasture.
2nd „	Barley.	5th „	Pasture.
3rd „	Hay.	6th „	Oats.

This course of cropping suits all soils of the second medium quality in any altitude or position. The grasses to be sown as under:—

	Per Acre.		Per Acre.
Ray grass . . .	½ bushel.	Dogstail	2 lbs.
Cocksfoot . . .	½ „	Red clover . . .	8 „
Meadow fescue . .	2 lbs.	White clover . .	4 „
Meadow catstail .	2 „	Trefoil	2 „

The soils of this kind that are the most inferior in quality, and the most elevated in the range of cultivation, are cropped as follows:—

1st year .	Turnips.	5th year	Pasture.
2nd „ .	Oats.	6th „	Pasture.
3rd „ .	Hay or pasture.	7th „	Pasture.
4th „ .	Pasture.	8th „	Oats.

The time of pasture may be so extended as to maintain the grassy herbage in a sweet and sound condition; so soon as it sickens and becomes brown, from the weakness of the land and the wetness of the climate, the land must be ploughed for the crop of oats, renewed by fallowing and manuring, and resown with fresh grasses, as follows:—

	Per Acre.		Per Acre.
Ray grass . . .	½ bushel.	Sheep's fescue . .	2 lbs.
Cocksfoot . . .	½ "	Red clover . . .	4 "
Meadow catstail .	4 lbs.	White clover . .	2 "
Crested dogstail .	2 "	Trefoil	2 "
Hand fescue . .	2 "		

Every sort of peaty loams is favourable to the action of artificial manures, and bones and guano never show their value more conspicuously than on peaty and moorish lands of an earthy description. The earthy ingredient is generally composed of gritty particles of the unreduced rock of primary structure, and the finer pulverization descends from the same source which has supplied all the earths and rocks in the world, according to a recent and seemingly not a very unjustifiable opinion. Bones delight more than guano in the gritty soils of the direct rocky foundation; the latter stimulant likes a more loamy softness and a more lenient texture for the development of its action. No soils in Britain suit bones so well as the siliceous and quartzy strata of the primary alluvium, which seems to possess some peculiar property that very readily and powerfully developes the action of bones.

The value of these lands is low, as the situation confines the use of the valuable plants, and restricts the animals that are bred to the inferior sorts. The produce of any kind is small, and the value of it must be corresponding. The acreable estimate may vary with the quality of the soil, from 8*s.* to 15*s.* The lands are easily wrought, and no large expense is incurred in the cultivation.

Fenny Soils

resemble loams, and if the latter term comprehends every kind of fine earths, it will embrace the surface alluvium of the fens as well as of the chalk and the sandstones. The fenny formations differ widely from moss, as they are putrescent, while the latter is phosphorescent, and has inflammable qualities that are wholly removed from bodies that have undergone the process of ultimate decay. The quality of fenny lands is very rich, while moss is as generally sterile, which is thought to arise from the want of the putrid fermentation. The general colour of the fenny loam is a light gray, and when the black hue does occur, the viscous adhesion denotes the presence of the putrid reduction of the elements of composition. The deepest alluvium is wet and requires surface draining, and much of the surface ground is used in grass; where the edges of the alluvium overlie the subjacent formations of chalk and oolite, dry earthy soils are formed, which most properly fall under the denomination of loams, as they are fine in texture, dry in composition, and admit every action of manure which is capable of being exerted on any occasion. The crops are very large on the land of the best sorts, though the bulk and quantity are more prominent than the quality of the ripened seed crops. The root crops are most abundant, and are as usual followed by the culmiferous plants in a corresponding bulk. Rape and cole grow most luxuriantly, and being consumed on the ground by sheep, the land is thereby well prepared for a crop of wheat, which very fittingly succeeds the broad-leaved and succulent vegetable. Rape is frequently converted into a seed-bearing crop, for the purpose of obtaining the oil which is contained in the seeds, and the husks are pressed into cakes, which are useful as food for cattle and sheep, and also as a manure when reduced to powder. The peculiar nature of the soil is more favourable to the growth of stems and leaves than to the formation of solid bulbs; but the want of these esculent roots is somewhat compensated by the large bulk of leaves, and the abundance of oily seeds, according as the crop is used for seeding or for maturing the fruits. The gross and dull nature of the soil produces ripened grains that are thick in the skin and coarse in the farina; but these defects are compensated by the large returns of every crop sown. And these returns are more certain than where the lands are more liable to be affected by local circumstances.

The best fenny soils are cropped as follows:—

1st year .	Cole fed off with sheep.	4th „	Wheat.
2nd „ .	Oats.	5th „	Clover.
3rd „ . .	Beans.	6th „	Wheat.

Oats answer better than wheat after the cole, the crop yielding eight to ten, or more, quarters an acre. A complete summer fallow is indispensable, to keep the land free of perennial root weeds.

The above rotation applies to the richest fen lands, which are placed on the deep alluvium. The dry earthy soils that constitute the edges of the formation, and which overlap the contiguous deposits of chalk and oolite, are weaker in quality, and are best used in the alternate system of grass and crops. The best qualities, which possess a good depth of stratum from lying near to the alluvial bed, and which are capable of producing beetroot and potatoes, are best used as under:—

1st year .	Green crops, beet and potatoes.	3rd year . .	Hay.
2nd „ .	Wheat.	4th „ . . .	Pasture.
		5th „ . . .	Oats.

Or—

4th year . .	Oats.	6th year . .	Wheat.
5th „	Beans & peas.		

Then barley is grown in the second year instead of wheat.

Beans are advantageously cultivated on these lands, as their loaminess permits spring cultivation, and the climate is also favourable.

The rotation of five years (changed into six, according to local peculiarities) is, of all others, the most suitable and advantageous, as it includes every profitable plant, and allows the most scientific alternations in the arrangements of succession.

The weakest qualities of fenny loams are dry and loose in texture, shallow in the stratum, and not very productive. The composition of the soil encourages the growth of turnips and the action of artificial manures, and wherever a crop of turnips can be produced, the other cultivated plants will follow in at least a fair abundance. Sheep thrive on such lands, and the system of pasturage becomes eligible, as under:—

1st year .	Turnips.	4th year .	Pasture.
2nd „ .	Barley.	5th „ .	Pasture.
3rd „ .	Hay or pasture.	6th „ .	Oats.

This rotation admits no superior for all weak clayey lands.

The grasses are sown as under:—

	Per Acre.		Per Acre.
Ray grass	½ bushel.	Sheep's fescue . .	4 lbs.
Cocksfoot	½ „	Red clover . .	8 „
Dogstail	4 lbs.	White clover . .	4 „
Hand fescue . . .	4 „	Trefoil	2 „

The grasses for the best loams are used for the best fenny soils.

The value of the fenny soils in the three qualities now mentioned may be stated at 40*s*., 25*s*., and 15*s*. per acre. The two last qualities of land are peculiarly adapted for sheep, for which the turnips and pasture become the special provisions. The soils are easily wrought and cleared of weeds, and seldom fail to return a profit for labour.

In turnip farming, a grand secret consists in husbanding for the summer use the moisture which has been acquired by the land during the winter. The success of the turnip crop depends very much, in some cases wholly and entirely, on the moisture which the land contains when the seed is committed to its bosom. In Scotland and the north of England the due quantity of moisture is seldom or never wanting; in these countries the soils are loamy and closely porous both to heat and moisture; the rains are frequent and copious, and the dews are heavy and abundant. But in south Britain, where the soils are gritty and crumbling, and the rains much less frequent, and wanting for several weeks together, the constant exposure of the land by repeated ploughings, dissipates the moisture wholly from the soil, and the land becomes a collection of dry clods, in which seeds fail to vegetate during the driest season of the year. This fact is proved by the constant experience of the cultivators of turnips. A very valuable suggestion may be made, that all turnip lands, of any kind or denomination, be wholly prepared by some grubber, or Finlayson's harrow, which, by the duck-footed shares, or forward pointed circular tires, will move and pulverize the soil to the required depth without turning it up and exposing it to evaporation, and will also drag to the surface the roots of weeds without cutting them into short pieces, as is often done by the share of the plough, and impedes the cleaning of the land. The winter ploughing must be deeply done in 7 or 8 in., in order that the scuffler may have plenty of soil on which to work the preparation. The grubbings or scufflings must be done alternately lengthwise and crosswise, and continued till the pulverization and cleaning be fully effected, and the time of sowing the crop has arrived. On the hard bottoms of the heavier loams and gravels a ploughing done in the mid-season will much assist the grubber, and raise fresh earth to be mixed in the upper pulverization; but on a large part of loamy lands the winter's ploughing will afford an ample tilth for the grubber, as the subsoils are soft and easily penetrated. The flattened surface of the land, from the action of the grubber, presents the same readiness to be drilled as is effected by ploughing and harrowing. By this mode of preparing turnip lands less exposure is made of the soil than by ploughing, the moisture is better preserved, and the weeds are more thoroughly taken from the land. It is also less expensive, as a grubbing will comprehend several ploughings, and will require less harrowing to accompany its action. The suggestion promises a large benefit to turnip farming.

CHAPTER XII.

General Estimate of Loamy Soils.—Intrinsic Properties and External Use.—The Pattern afforded by them to the Artificial Similarities, and Improvement by being dug and mixed with Hot Lime.

Loamy soils, or the lands that are reduced to the fineness of texture suitable to the cultivation of green crops, exhibit the state or condition in which the different earths must be mixed, in order to afford the bed or matrix that is most agreeable to the nature of plants, and conducive to their growth and maturity. All experience has shown that a comminution of particles is essential to the preparation of ground for the reception of seeds with a view to future growth, and that a variety of ingredients is necessary in order to promote the mutual action. Chemistry has learned that reciprocal action takes place only between the ultimate elements of matter, and that bodies which do not combine by themselves are made to do so by the addition of other substances. This varied combination forms the very peculiar excellence of loams, as it constitutes the foundation, in more than one instance, of the ways and modes in which the action of the mixture is exerted. The modifications of loam show that the quality of the soil decreases in proportion as the number of ingredients is lessened, or as one substance obtains an undue preponderance; and that the fertility is increased in proportion to the variety and intimate mixture of the materials. On this point no mistake of judgment can be made, as the evidences are most certain, and the results wholly beyond dispute. These mixtures are very uncertain in location, and capricious in diversity, exhibiting, as much as any other geological formation, contemporaneous differences carried to an extreme, and local diversity overcoming all general agreement. Though the alluvial deposits seem to have been made under a tranquillity of circumstances widely different from the underlying stratifications that extend to the oldest known deposit, yet the differences are not fewer in number, nor are the marks more apparent of any general law or regulated order in mixing the ingredients, or in arranging the layers; but whatever differences exist in the number and mixture of the substances, or in the quantity and quality of the deposit, every finely-comminuted earth possesses the property of favouring the growth of plants, in whatever degree the inherent virtue may be bestowed. This general quality is seldom, or rather never, wanting, unless there be present some noxious ingredient, as in the case of the iron sands, where the mineral oxide very much impairs the productive quality of the arenaceous earths; but the general fact is almost without exception.

Loams are mixed with a greater or less quantity of exuvial matter, being the organized remains of animals and vegetables which have lived and died on the surface of the ground. On the quantity and quality of this exuvial matter, the state of reduction it has attained, and the mode or manner in which it is mixed with the primary earths, the fertility of loamy soils is found almost wholly to depend. This substance is called "humus," and has been before noticed. The decomposing action of the earthy matters on the humus will form a very considerable part of the usefulness of loams, and it will be exerted according as calcareous matter is abundant or wanting in the soil, and the nature of it active or inert. By it the humus is rendered soluble, which prevents a mortar being formed by the clay and sand, that would harden too readily, and prevent the influence of the air from reaching the roots of plants. The pure earths are in themselves almost barren. Sand lets the moisture run through it and evaporate rapidly; clay retains it, but locks it up in its own substance, and does not allow the tender young roots of plants to push through it. Chalk has the same mechanical quality, besides containing very little organic and soluble matter, from which plants derive their chief increase. Sand and clay alone will not make a rich soil; but calcareous matter being joined to both, the humus is acted upon as before mentioned, and the earths are formed into a very porous and fruitful composition; and the mode of the mixture, with the relative quantity of the ingredients, constitutes the quality of the valuable alluvium.

But the intrinsic pre-eminence of loam proceeds from two qualities: the absorption and retention of moisture, and the duly-regulated power of conducting caloric, or the cause of heat. These two properties are the chief requisites of fertility, and in order to procure them, a certain number of ingredients are necessary, and a peculiar mixture of the elements that are present. For the absorption and retention of moisture, clay and sand correct the mutual defects of each other; the sand lessens the very strong affinity of clay, and the latter body hinders the too rapid transition of moisture through all sandy formations. Calcareous matter absorbs moisture very greedily, but in a limited quantity, and assists the sand in reducing the extreme property of clay in that respect. Humus, or the exuvial matter of organized life, imbibes a fair quantity of moisture, and holds it in the same ratio of moderation, evaporating moderately, and retaining it equably. Hence the loamy soils possess the most useful quantity of moisture, which is regulated by the composition of the soil, in the preponderance of clay or sand, and by a limited or ample mixture of humus and calcareous matter. In the calorific qualities, the same properties exist. Clay is heated with difficulty, owing to the very large presence of moisture in its substance; sand radiates the heat very rapidly, and is as easily cooled; calcareous matters are the products of igneous action, and impart caloric in some degree to every contiguity, and humus, being the residue of a living activity, retains the quality of its original existence. The repulsive obstinacy of the clay is overcome by the moderated action of the three adjuncts of composition; and the opposite extreme of the sand is reduced by the clay, and regulated by the humus and the lime in conjunction. In this way, the excellence of loam is produced in the two qualities that are essential to any large prosperity of vegetable life,—heat and moisture. Without these qualities being present in a regulated abundance, the fruits of labour will ever be scantily rewarded, and nearly or altogether denied.

Another most valuable property in the loamy kinds of land consists in the quantity and quality of the exhalations that arise from the surface of the ground, on which a large part of the value and production of all soils is known to depend. Evaporation arises from liquid surfaces, and exhalations are extracted from the surfaces of solid and hardened bodies, which hold the moisture in combination with other matters, and part with it to the rays of the sun, according to the nature of the substances with which it is associated. The quality of exhalations depends upon the origin of extraction being cold or warm, wet or dry, airy or humid, clammy or evanescent, by reason of the primary nature of their sources, and the external circumstances to which they are exposed. A high or low situation, airy or confined, cold or sunny, favourable or bleak in the aspect, and level or declining, will very materially influence the number and nature of the exhalations that arise from any extent of surface; and the effects on vegetable life will uniformly correspond. An exhalation is composed of dry subtile corpuscles or effluvia, loosened from hard terrestrial bodies, either by the heat of the sun or the agitation of the air, or some other cause, and emitted upwards to a certain height of the atmosphere, where, mixing with the vapours, they help to constitute clouds, and return in the form of dews, mists, and rains. Different substances yield exhalations with very different degrees of facility, a circumstance dependent very probably upon the less or greater cohesion with which their particles adhere. The chief circumstances that influence the process are—extent of surface, and the state of the air as to temperature, dryness, stillness, and density. The exhalations that arise from the loamy soils comprise the vapour of water that contains in solution the carbonate of lime that is found in the soil; and, consequently, carbonic acid gas will be held in mixture. In rising from the ground the vapours surround and rest upon the growing vegetables, which imbibe nourishment from the air, and are consequently much benefited by the favourable quality of the exhalations arising from the ground by the action of heat. So soon as rain falls, the qualities of the air are carried down to the earth, when the beneficial influence is again exerted. Exhalations, being condensed, fall at once to the ground in the form of rain, or they assume a middle station as dews and fogs, which ultimately fall to the earth as pure water. But growing plants derive the most benefit from the ascent of exhalations, as the passage is much more leisurely than the descent, and more time is granted for the formation of vapour, and its introduction into the vascular system of vegetables. The agency of heat is at the same time exerted, and the favourable combination of moisture and caloric constitute the elements of every abundant produce of vegetation.

One very great advantage of loamy ground consists in its capability of being ploughed and cultivated, in every operation, by two horses, and with implements which, being of a comparatively light construction, are consequently used at less cost. This property is very valuable when contrasted with the clays of the chalk and the oolites, where the strength of four horses is required, and an implement of much weight and original cost. Another fully equal advantage lies in the possibility of the lands being cultivated at almost any season of the year, and during any kind of weather. This quality gives it another decided superiority over clayey lands, which can only be tilled during peculiar weather that forms a medium between wet and dry, and which is not very frequent, nor of long duration. But loams are seldom troublesome to the farmer in that respect. The last and not least superior quality of loams consists in the excellence of the produce that is raised on the grounds, of the grains that are matured, and of the animals that are reared and fattened by the grassy herbage. Crops of any kind are seldom deficient on loams, unless the quality of the soil be very low, as on the sands and chalks, where the land hardly admits the appellation. The green crops thrive and the grains prosper, and the surface-grasses afford a sound and wholesome bite to animals throughout the year. Sheep never experience any damage from the wetness of the surface, as on the clays, nor swallow any noxious decaying vegetation from the grassy plants becoming brown and withered by an excess of water, as on the argillaceous formations.

The constitution of loams presents for serious consideration the example of fruitfulness that results from the combined and intimate mixture of a number of ingredients, which are different in their nature, and adverse in their quality. It offers to view the cause of fertility, and the adoption of the process that has produced it occurs to the reflection of sober calculation. The climate of any country has very great influence on the productions of the soil, and also on the lands which are used for that purpose. In the climate of France, near Paris the most productive loam is composed of equal portions of fine sand, clay, and chalk. The greater the natural moisture of any climate, the greater proportion of sand is required to make a fertile loam; and the greater the proportion of humus, the less sand will be required to temper the clay. In the climate of England the soil which is generally preferred for cultivation is a loam rather light than heavy, at least half of which is siliceous sand, one-third clay, and the rest chalk. Such a soil will produce almost any crops, being not too stiff for carrots and turnips, nor too loose for wheat and beans. It is easily cultivated at any season of the year, provided the subsoil be not too retentive of moisture; frequent repetitions of manure are required to restore the humus which vegetation has consumed, and the weeds, which rise on all fertile lands, must be killed. All attempts to improve the nature of soils must have for their object the bringing it to a state of loam, by the addition of those substances which are deficient, If there is too much clay, chalk and sand may be added, or a portion of the clay may be calcined by burning, in order to destroy its attraction for water, and thus act the part of sand in forming the loam. Limestone and gravel are also efficacious for this purpose; they not only correct too great porosity and too great tenacity, but also act chemically on the organic matter in the soil, rendering the humus soluble, and fit to be taken up by the roots of plants. If there is too much sand, marl composed of clay and chalk is the remedy. It is true that chemical combination is beyond the power of man, but a mechanical mixture affords the ready means for the action of nature, and cultivation and time may fully accomplish the process.

Good loams require much less tillage than stiffer soils, and will bear more stirring to clean them than sands. Hence they are cultivated more economically, and more easily kept free from useless weeds, while the produce is more certain and more abundant. They can be impregnated to a higher degree with enriching manures, without danger of root-fallen crops, or of too great abundance of straw at the expense of the grain. For artificial meadows they are eminently proper: all the grasses grow well on good loams, when they are on a dry sound subsoil, which is an indispensable condition in all good lands. Sheep and cattle can be depastured on them during the whole year, except when there is snow on the ground. If there should be means of irrigation, no soil is better suited to it than a light loam on a bed of gravel; or even if the subsoil is clay, provided sufficient under-draining prevent the water from stagnating between the soil and subsoil, which, as practical men very properly express it, would poison any land.

A loamy soil requires less dung to keep it in heart than either clay or sand; for, while it is favourable to the process by which organic matter buried deep in the soil is converted into insoluble humus, it also permits that part of it which is nearer to the surface to attract oxygen from the air, and thus it is converted into a soluble extract, which is to the roots of plants what the milk of animals is to their young—a ready-prepared food easily converted into vegetable juices.

In the last chapter of the section on "Clay Lands," the manner by which all argillaceous soils could be converted into fruitful loams, and the expense of making the alteration was detailed. It is now proposed to effect, by the same agency, the conversion of all loamy earths into soils of a better quality, by digging with the spade a portion of the subsoil, mixing it with hot lime, and commingling together into one mass the upper stratum, the lime, and the subsoil. The best clayey loams recline on a bottom of hard dry clay, which will require a heavy labour in digging; but, as the upper soil is loamy and friable, the quantity of hot lime required may be diminished by one-third, and consequently the whole expense will be £20 per acre, instead of £30. Sandy loams rest upon a bed of aggregated detritus of many substances and qualities, but which may be converted into good earth by means of mixing with lime, and exposure to the atmosphere. Such lands will require to be dug to the depth of one foot below the surface; but, as the composition is much warmer than clay, loose, and little adhesive, a shorter time will effect the purpose, and the digging will also be more easily performed. One-half the expense of clay lands will be sufficient, or £10 to £12 per acre. Gravelly and iron-sandy bottoms are more compact, and will need more labour in digging; and as the ingredients of the upper soil are aggregated and often somewhat noxious, and the materials of the subsoil are more harsh and repulsive than of the sandy loams, the cost may be stated at one-half of the estimate of the primary clays, or at £15 per acre. Some differences will always happen from local peculiarities, and contingent circumstances.

It is conceived, that by digging the soil with the spade, and mixing it with quick-lime, every kind of soil may be greatly improved: clay lands of every denomination be changed into rich loams, and the present soils of fine earths into lands of a deeper staple and a much richer consistence. After the volatile ingredients of lime have exerted their action and disappeared, the earthy base relapses into a mollified mass, which possesses a mucilaginous quality that is imparted to the other materials with which it is mingled. The whole mixed formation is changed in condition and capacity by the violent action of heat, to which the substances have been exposed; the old properties are banished, and new qualities are conferred that are most favourable to fertility,—a circumstance that almost invariably attends the action of fire. The suggestion is no wild chimera of the brain, but the offspring of reason and the understanding; it is a portion of the lofty aim that ought to be constantly before the eyes and incite the actions of man. If perfection cannot be attained in any matter, a very near approach may be made to it.

It might be an interesting and highly-useful inquiry to ascertain the effect of the contact of the various kinds of earth, moistened with water, in exciting galvanic action, which no doubt greatly influences the chemical affinities of the elements from which the plants derive their increase. It is a subject which has scarcely ever been noticed, and we would strongly recommend scientific experiments in this branch of vegetable physiology. It may be very reasonably supposed that a chief value of loams consists in their provoking the galvanic action, by reason of the number of minute ingredients, which are moistened in the necessary degree for the exciting contact. And this quality may result from the peculiar composition of the soil,—from the substances being present in number and the relative quantity, the condition of existence, and the blending of the ingredients. On these properties every chemical and natural quality is found to depend.

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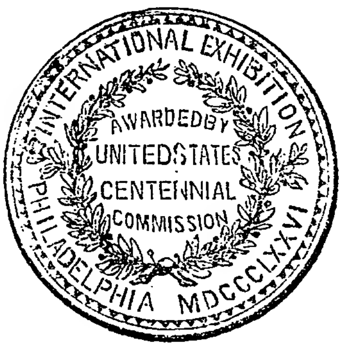

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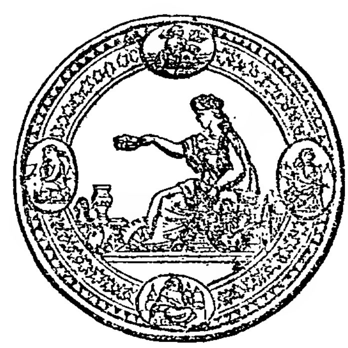

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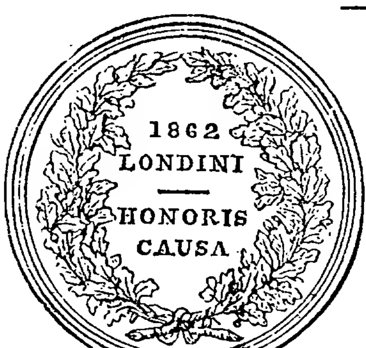

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